Modern Carpentry

Fred T. Hodgson

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MODERN CARPENTRY

A Practical Manual

A complete guide containing hundreds of quick methods for performing work in carpentry, joining and general wood work, written in a simple, everyday style that does not bewilder the working man. Illustrated with hundreds of diagrams which are especially made so that anyone can follow them without difficulty.

TWO VOLUMES IN ONE

By
FRED T. HODGSON, Architect

Illustrated

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PREFACE TO SECOND EDITION.

MODERN CARPENTRY.

The necessity of preparing a second edition of this work has become so urgent that its publication cannot be longer delayed. The demand for it has almost outgrown our means of production, and our supply is about exhausted, so we hasten to take advantage of this condition to enlarge and improve the work and render it more acceptable and valuable than ever. The additions and improvements now made to the work, are of so very useful and practical a character, that we are sure they will prove of benefit to the workman, and to the general student of the carpenter and joiners' art.

It is hardly necessary for me to indulge in a long preamble setting forth the good qualities contained in the contents of this work, as all this has been before the people now for several years; all recent developments in the carpenter trade, however, have been added, so that the present volume will be found to contain the very latest practice of doing things. The additional matter and diagrams will, I am sure, commend themselves to the workman, and will, I hope, prove a help to him in his everyday labors.

FRED T. HODGSON.

MODERN CARPENTRY

PART I

CARPENTER'S GEOMETRY

CHAPTER I

THE CIRCLE

While it is not absolutely necessary that, to become a good mechanic, a man must need be a good scholar or be well advanced in mathematics or geometry, yet, if a man be proficient in these sciences they will be a great help to him in aiding him to accomplish his work with greater speed and more exactness than if he did not know anything about them. This, I think, all will admit. It may be added, however, that a man, the moment he begins active operations in any of the constructional trades, commences, without knowing it, to learn the science of geometry in its rudimentary stages. He wishes to square over a board and employs a steel or other square for this purpose, and, when he scratches or pencils a line across the board, using the edge or the tongue of the square as a guide, while the edge of the blade is against the edge of the board or parallel with it, he thus solves his first geometrical problem, that is, he makes a right angle with the edge of the board. This is one step forward in the path of geometrical science.

He desires to describe a circle, say of eight inches diameter. He knows instinctively that if he opens his

compasses until the points of the legs are four inches apart,—or making the radius four inches—he can, by keeping one point fixed, called a "center," describe a circle with the other leg, the diameter of which will be eight inches. By this process he has solved a second geometrical problem, or at least he has solved it so far that it suits his present purposes. These examples, of course, do not convey to the operator the more subtle qualities of the right angle or the circle, yet they serve, in a practical manner, as assistants in every-day work.

When a man becomes a good workman, it goes without saying that he has also become possessor of a fair amount of practical geometrical knowledge, though he may not be aware of the fact.

The workman who can construct a roof, hipped, gabled, or otherwise, cutting all his material on the ground, has attained an advanced practical knowledge of geometry, though he may never have heard of Euclid or opened a book relating to the science. Some of the best workmen I have met were men who knew nothing of geometry as taught in the books, yet it was no trouble for them to lay out a circular or elliptical stairway, or construct a rail over them, a feat that requires a knowledge of geometry of a high order to properly accomplish.

These few introductory remarks are made with the hope that the reader of this little volume will not be disheartened at the threshold of his trade, because of his lack of knowledge in any branch thereof. To become a good carpenter or a good joiner, a young man must begin at the bottom, and first learn his A, B, C's, and the difficulties that beset him will disappear one after another as his lessons are learned. It

must always be borne in mind, however, that the young fellow who enters a shop, fully equipped with a knowledge of general mathematics and geometry, is in a much better position to solve the work problems that crop up daily, then the one who starts work without such equipment. If, however, the latter fellow be a boy possessed of courage and perseverance, there is no

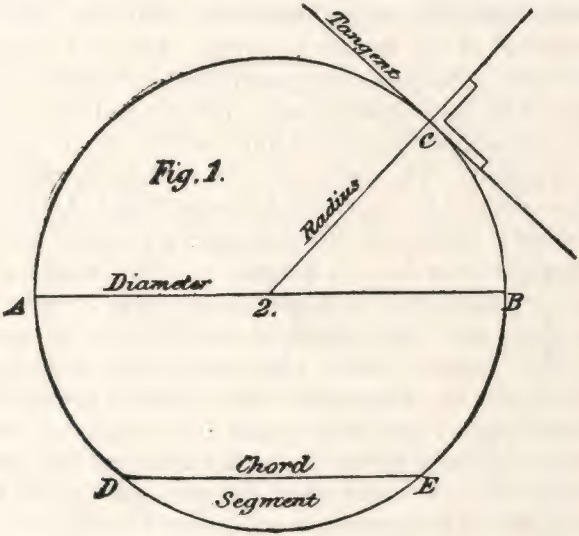


Fig. 1.

reason why he should not "catch up"—even overtake—the boy with the initial advantages, for what is then learned will be more apt to be better understood, and more readily applied to the requirements of his work. To assist him in "catching up" with his more favored shopmate, I propose to submit for his benefit a brief description and explanation of what may be termed "Carpenter's Geometry," which will be quite

sufficient if he learn it well, to enable him to execute any work that he may be called upon to perform; and I will do so as clearly and plainly as possible, and in as few words as the instructions can be framed so as to make them intelligible to the student.

The circle shown in Fig. 1 is drawn from the center 2, as shown, and may be said to be a plain figure within a continual curved line, every part of the line being equally distant from the center 2. It is the simplest of all figures to draw. The line AB, which cuts the circumference, is called the diameter and the line DE is denominated a chord, and the area enclosed within the curved line and the chord is termed a segment. The radius of a circle is a line drawn from the center 2 to the circumference C, and is always one-half the length of the diameter, no matter what that diameter may be. A tangent is a line which touches the circumference at some point and is at right angles with a radial line drawn to that point as shown at C.

The reader should remember these definitions as they will be frequently used when explanations of other figures are made; and it is essential that the learner should memorize both the terms and their significations in order that he may the more readily understand the problems submitted for solution.

It frequently happens that the center of a circle is not visible but must be found in order to complete the circle or form some part of the circumference. The center of any circle may be found as follows: let BHC, Fig. 2, be a chord of the segment H; and BJA a chord enclosing the segment. Bisect or divide in equal parts, the chord BC, at H, and square down from this point to D. Do the same with the chord AJB, squaring over from J to D, then the

point where JD and HD intersect, will be the center of the circle.

This is one of the most important problems for the carpenter in the whole range of geometry as it enables the workman to locate any center, and to draw curves he could not otherwise describe without this or other similar methods. It is by aid of this problem that through any three points not in a straight line, a

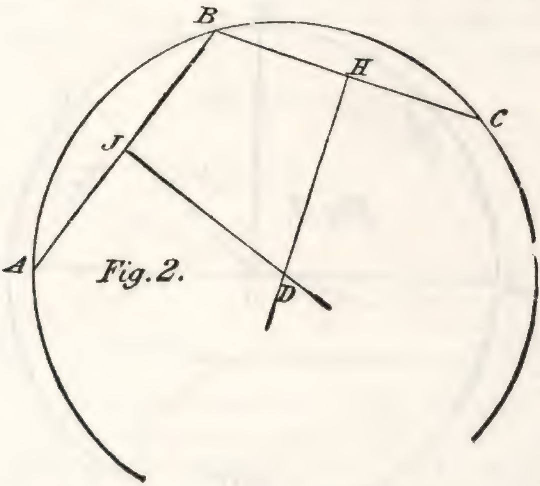


Fig. 2.

circle can be drawn that will pass through each of the three points. Its usefulness will be shown further on as applied to laying out segmental or curved top window, door and other frames and sashes, and the learner should thoroughly master this problem before stepping further, as a full knowledge of it will assist him very materially in understanding other problems.

The circumference of every circle is measured by being supposed to be divided into 360 equal parts, called *degrees*; each degree containing 60 *minutes*, a

smaller division, and each minute into 60 ***seconds,*** **a** still smaller division. Degrees, minutes, and seconds are written thus: 45° 15′ 30″, which is read, forty-five degrees, fifteen minutes, and thirty seconds. This, I think, will be quite clear to the reader. Arcs are measured by the number of degrees which they contain: thus, in Fig. 3, the arc AE, which contains 90°, is called a quadrant, or the quarter of a circumference, because

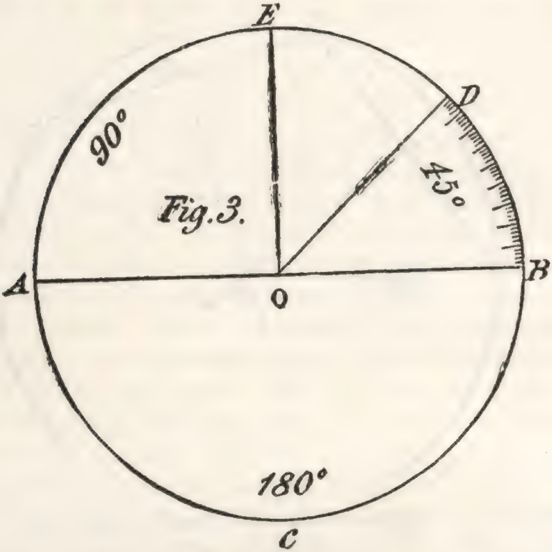


Fig. 3.

90° is one quarter of 360°, and the arc ABC which contains 180°, is a semi-circumference. Every angle is also measured by degrees, the degrees being reckoned on an arc included between its sides; described from the vertex of the angle as a center, as the point O, Fig. 3; thus, AOE contains 90°; and the angle BOD, which is half a right angle, is called an angle of 45°, which is

the number it contains, as will be seen by counting off the spaces as shown by the divisions on the curved line BD. These rules hold good, no matter what may be the diameter of the circle. If large, the divisions are large; if small, the divisions are small, but the manner of reckoning is always the same.

One of the qualities of the circle is, that when divided in two by a diameter, making two semicircles, any chord starting at the extremity of such a diameter, as at A or B, Fig. 4, and cutting the circumference at any point, as at C, D or E, a line drawn from this

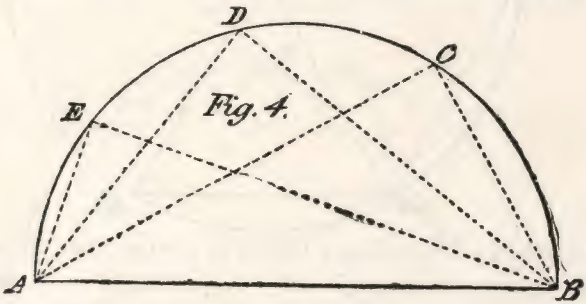


Fig. 4.

point to the other extremity of the diameter, will form a right angle—or be square with the first chord, as is shown by the dotted lines BCA, BDA, and BEA. This is something to be remembered, as the problem will be found useful on many occasions.

The diagram shown at Fig. 5 represents a hexagon within a circle. This is obtained by stepping around the circumference, with the radius of the circle on the compasses, six times, which divides the circumference into six equal parts; then draw lines to each point, which, when completed, will form a hexagon, a six-sided figure. By drawing lines from the points obtained in the circumference to the center, we get a

three-sided figure, which is called an equilateral triangle, that is, a triangle having all its sides equal in

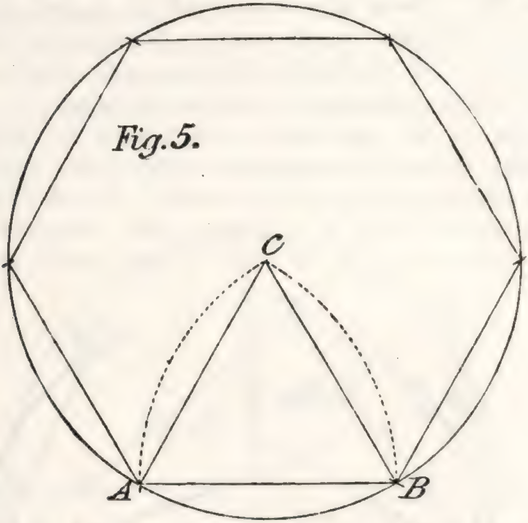


Fig. 5.

length; as AB, AC and BC. The dotted lines show how an equilateral triangle may be produced on a straight line if necessary.

The diagram shown at Fig. 6 illustrates the method of trisecting a right angle or quadrant into three equal parts. Let A be a center, and with the same radius intersect at E, thus the quadrant or right angle is divided into three equal parts.

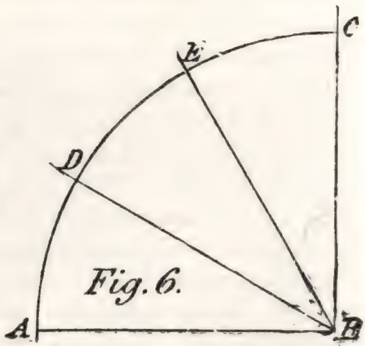


Fig. 6.

If we wish to get the length of a straight line that shall equal the circumference of a circle or part of circle or quadrant, we can do so by proceeding as follows: Suppose Fig. 7 to represent half of the circle, as at ABC; then draw the chord BC, divide it at P, join it at A; then four times PA is equal to the circumference of a circle whose diameter is AC, or equal to the curve CB.

To divide the quadrant AB into any number of equal parts, say thirteen, we simply lay on a rule and make the distance from A to R measure three and one-

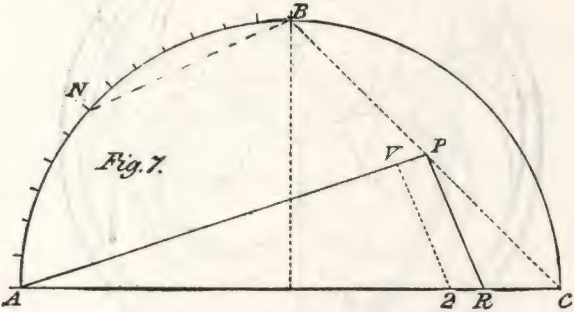


Fig. 7.

fourth inches, which are thirteen quarters or parts on the rule; make R2 equal one-fourth of an inch; join RP; draw from 2 parallel with RP, cutting at V; now take PV in the dividers and set off from A on the circle thirteen parts, which end at B, each part being equal to PV, and the problem is solved. The "stretchout" or length of any curved line in the circle can then be obtained by breaking it into segments by chords, as shown at BN.

I have shown in Fig. 5, how to construct an equilateral triangle by the use of the compasses. I give at

Fig. 8 a practical example of how this figure, in connection with circles, may be employed in describing a figure known as the trefoil, a figure made much use of in the construction of church or other Gothic work and for windows and carvings on doors and panelings. Each corner of the triangle, as ABC, is a center from which are described the curves shown within the outer circles. The latter curves are struck from the center

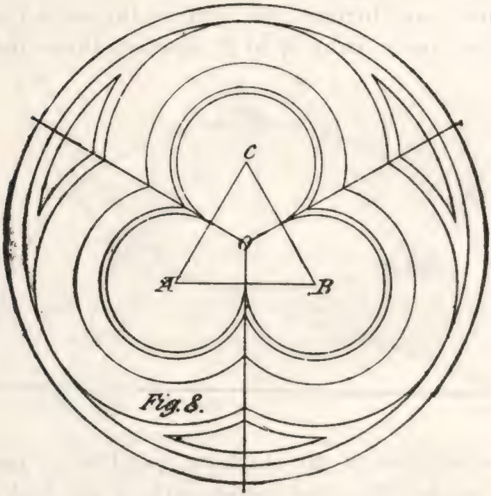


Fig. 8.

O, which is found by dividing the sides of the equilateral triangle and squaring down until the lines cross at O. The joint lines shown are the proper ones to be made use of by the carpenter when executing his work. The construction of this figure is quite simple and easy to understand, so that any one knowing how to handle a rule and compass should be able to construct it after a few minutes' thought. This figure is the key to most Gothic ornamentation, and is worth mastering.

There is another method of finding the length or "stretchout" of the circumference of a circle, which I show herewith at Fig. 9. Draw the semicircle SZT, and parallel to the diameter ST draw the tangent UZV; upon S and T as centers, with ST as radius, mark the arcs TR and SR; from R, the intersection of the arcs, draw RS and continue to U; also draw RT, and continue to V; then the line VU will nearly equal in

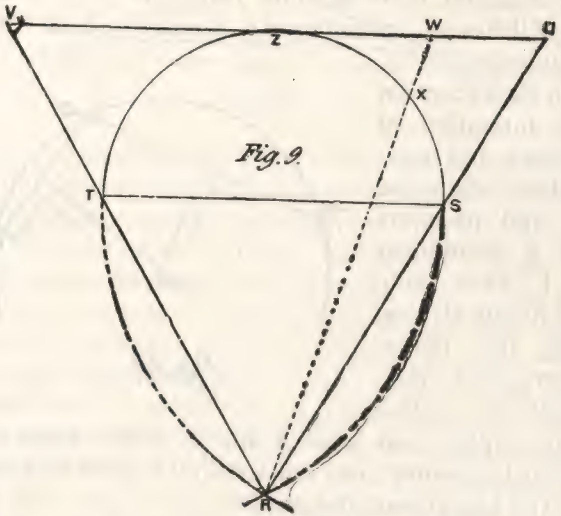


Fig. 9.

length the circumference of the semicircle. The length of any portion of a circle may be found as follows: Through X draw RW, then WU will be the "stretchout" or length of that portion of the circle marked SX. There are several other ways of determining by lines a near approach to the length of the circumference or a portion thereof; but, theoretically, the exact "stretchout" of a circumference has not been found by any of the known methods, either arith-

metically or geometrically, though for all practical purposes the methods given are quite near enough. No method, however, that is given geometrically is so simple, so convenient and so accurate as the arithmetical one, which I give herewith. If we multiply the diameter of a circle by 3.1416, the product will give the length of the circumference, very nearly. These figures are based on the fact that a circle whose diameter is 1—say one yard, one foot, or one inch—will have a circumference of nearly 3.1416 times the diameter.

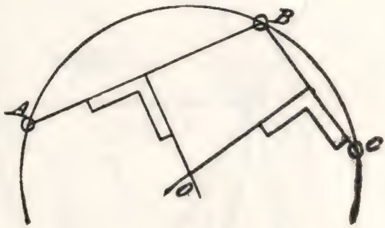


Fig. 10.

With the exception of the formation of mouldings, and ornamentation where the circle and its parts take a prominent part, I have submitted nearly all concerning the figure, the everyday carpenter will be called upon to employ, and when I approach the chapter on Practical Carpentry later on, I will try and show how to use the knowledge now given.

Before leaving the subject, however, it may be as well to show how a curve, having any reasonable radius, may be obtained—practically—if but three points in the circumference are available; as referred to in the explanation given of Fig. 5. Let us suppose there are three points given in the circumference of a circle, as ABC, Fig. 10, then the center of such circle can be found by connecting the points AB and BC by straight lines as shown, and by dividing these lines

and squaring down as shown until the lines intersect at O as shown This point O is the center of the circle.

It frequently happens that it is not possible to find a place to locate a center, because of the diameter being so great, as in segmental windows and doors of large dimensions. To overcome this difficulty a method

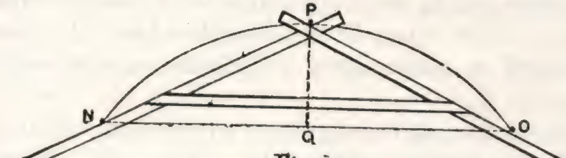


Fig. 11.

has been devised by which the curve may be correctly drawn by nailing three wooden strips together so as to form a triangle, as shown in Fig. 11. Suppose NO to be the chord or width of frame, and QP the height of segment, measuring from the springing lines N and O; drive nails or pins at O and N, keep the triangle close against the nails, and place a pencil at P, then slide the triangle against the pins or nails while sliding, and the pencil will describe the necessary curve. The arms of the triangle should be several inches longer than the line NO, so that when the pencil P arrives at N or O, the arms will still rest against the pins

CHAPTER II

POLYGONS

A polygon is a figure that is bounded by any number of straight lines; three lines being the least that can be employed in surrounding any figure, as a triangle, Fig. 1.

A polygon having three sides is called a trigon; it is also called an equilateral triangle. A polygon of four sides is call a tetragon; it is also called a square and an equilateral rectangle. A polygon of five sides is a pentagon. A polygon of six sides is a hexagon. A polygon of seven sides is called a heptagon. A polygon of eight sides is called an octagon. A polygon of nine sides is called a nonagon. A polygon of ten sides is called a decagon. A polygon of eleven sides is called an undecagon. And a polygon of twelve sides is called a dodecagon.

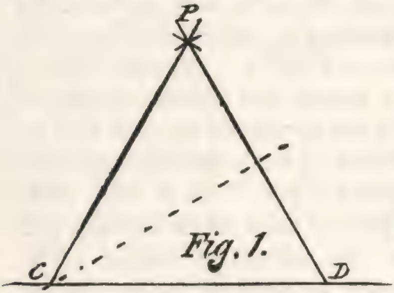


Fig. 1.

There are regular and irregular polygons. Those having equal sides are regular; those having unequal sides are irregular. Polygons having more than twelve sides are known among carpenters by being denominated as a polygon having "so many sides," as a "polygon with fourteen sides," and so on.

Polygons are often made use of in carpenter work, particularly in the formation of bay-windows, oriels, towers, spires, and similar work; particularly is this the case with the hexagon and the octagon; but the most used is the equilateral rectangle, or square; therefore it is essential that the carpenter should know considerable regarding these figures, both as to their qualities and their construction.

The polygon having the least lines is the trigon, a three-sided figure. This is constructed as follows: Let CD, Fig. 1, be any given line, and the distance CD the length of the side required. Then with one leg of the compass on D as a center, and the other on C, describe the arc shown at P. Then with C as a center, describe another arc at P, cutting the first arc. From this point of intersection draw the lines PD and PC, and the figure is complete. To get the miter joint of this figure, divide one side into two equal parts, and from the point obtained draw a line through opposite angle as shown by the dotted line, and this line will be the line of joint at C, or for any of the other angles.

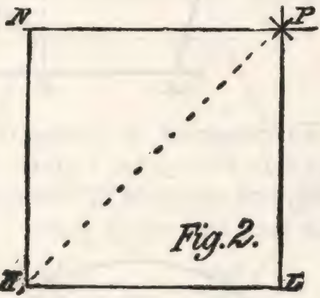


Fig. 2.

The square, or equilateral rectangle, Fig. 2, may be obtained by a number of methods, many of which will suggest themselves to the reader. I give one method that may prove suggestive. Suppose two sides of a square are given, LHN, the other sides are found by taking HL as radius, and with LN for centers make the intersection in P, draw LP and NP, which com-

pletes the figure. The miter for the joints of a figure of this kind is an angle of 45°, or the regular miter. The dotted line shows the line of "cut" or miter.

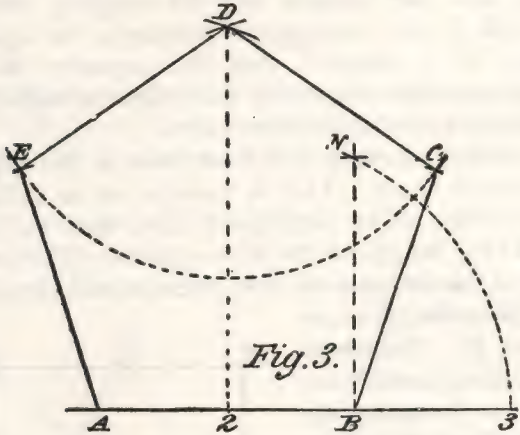


Fig. 3.

To construct a pentagon we proceed as follows: Let AB, Fig. 3, be a given line and spaced off to the length of one side of the figure required; divide this line into two equal parts. From B square up a line; make BN equal to AB, strike an arc 3N as shown by the dotted lines, with 2 as a center and N as a radius, cutting the given line at 3 Take A3 for radius; from A and B as centers, make the intersection in D; from D, with a

Fig. 4.

radius equal to AB, strike an arc; with the same radius and A and B as centers, intersect the arc in EC. By joining these points the pentagon is formed. The cut, or angle of joints, is found by raising a line from 2 and cutting D, as shown by the dotted line.

The hexagon, a six-sided figure shown at Fig. 4, is one of the simplest to construct. A quick method is described in Chapter I, when dealing with circles, but I show the method of construction in order to be certain that the student may be the better equipped to deal with the figure. Take the length of one side of the figure on compasses; make this length the radius of a circle, thus describe a circle as shown. Start from any point, as at A, and step around the circumference of the circle with the radius of it, and the points from which to draw the sides are found, as the radius of any circle will divide the circumference of that circle into six equal parts.

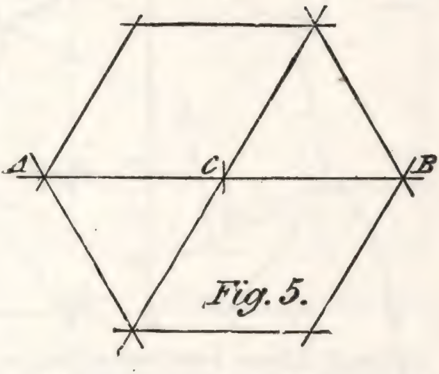


Fig. 5.

This figure may be drawn without first making a circle if necessary. Set off two equal parts, ABC, Fig. 5, making three centers; from each, with radius AC, make the intersection as shown, through which draw straight lines, and a hexagon is formed. The miter joint follows either of the straight lines passing through the center, the bevel indicating the proper angle.

The construction of a heptagon or seven-sided figure may be accomplished as follows: Let AB, Fig. 6, be a given line, and the distance AB the length of the side of the figure. Divide at K, square up from this point, then take AB for radius and B as a center; intersect the line from K at L; with same radius and A as center, draw the curve 2, 3; then take KL as radius, and from 2 as a center, intersect the circle at 3; draw from it to B, cutting at N, through which point draw from A; make AD equal B3; join A3 and BD; draw from 3 parallel with AD; draw from B through L, cutting at C; join it and A; draw from 3 parallel with AC; make 3H equal AB, and CE equal ND; join ED; draw from H parallel with 3C, cutting at F, join this line and E, which completes the heptagon. It is not often this figure is used in carpentry, though I have sometimes employed it in constructing bay windows and dormers, using the four sides, 3H, HF, FE, and ED. This makes a bold front, and serves well in a conservatory or other similar place.

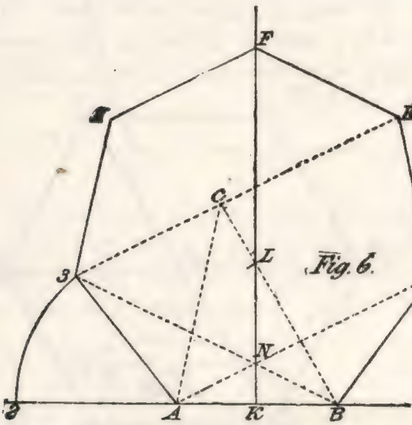


Fig. 6.

It is proper that the reader should know how to construct this figure, as it serves as an exercise, and illustrates a principle of drawing by parallels. a knowledge of which would be found invaluable to the ambi-

tious young carpenter, who desires to become, not only a good workman, but a good draftsman as well.

The octagon or eight-sided figure claims rank next to the square and circle, in point of usefulness to the general carpenter, owing partly to its symmetry of form, and its simplicity of construction. There are a great number of methods of constructing this figure, but I will give only a few of the simplest, and the ones most likely to be readily understood by the ordinary workman.

One of the simplest methods of forming an octagon is shown at Fig. 7, where the corners of the square are used as centers, and to the center A of the square for radius. Parts of a circle are then drawn and continued until the boundary lines are cut. At the points found draw diagonal lines across the corner as shown, and the figure will be a complete octagon, having all its sides of equal length.

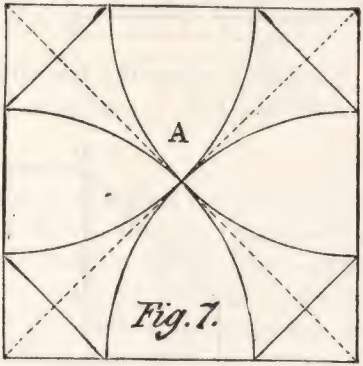


Fig. 7.

The method of obtaining the joint cut or miter for an octagon is shown at Fig. 8, where the angle ABC, is divided into two equal angles by the following process: From B, with any radius, strike an arc, giving A and C as centers, from which, with any radius, make an intersection, as shown, and through it from B, draw a line, and the proper angle for the cut is obtained, the dotted line being the angle sought. By this method

of bisecting an angle, no matter how obtuse or acute it may be, the miter joint or cut may be obtained. This is a very useful problem, as it is often called into requisition for cutting mouldings in panels and other work, where the angles are not square, as in stair spandrils and raking wainscot.

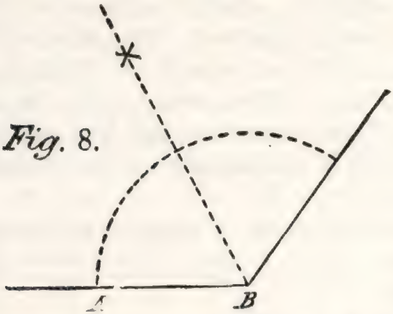


Fig. 8.

To construct an octagon when the length of one of its sides is given, as AB, Fig. 9, square up the two lines, AN, BF, then

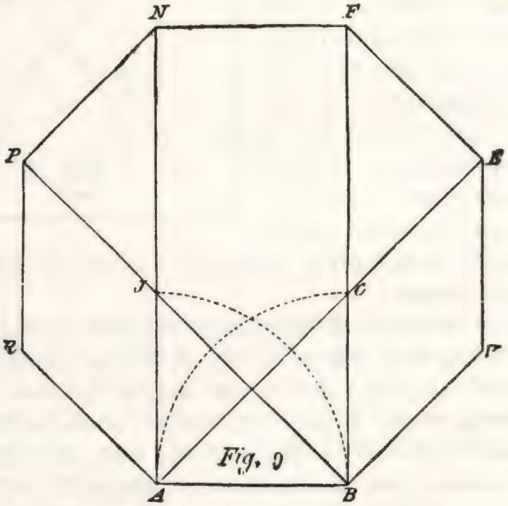
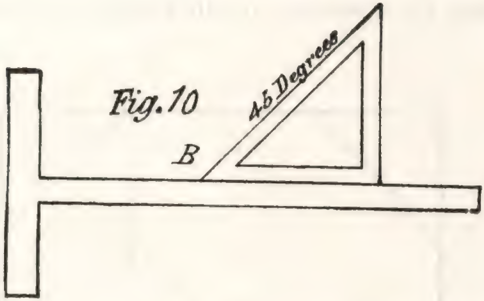


Fig. 9

take AB as radius with A and B as centers, and draw the arcs, cutting the two lines at C and J;

draw from AB, through CJ, and again from A draw parallel with BJ; then draw from B parallel with AC; make BV and CF equal AB; join EV; make CF equal CA; square over FN; join FE; draw NP parallel with AC, then join PR, and the figure is complete.



As the sides of all regular octagons are at an angle of 45° with each other, it follows that an octagon may be readily constructed by making use of a set square having its third side to correspond with an angle of 45°, for by extending the line AB, and laying the set square on the line with one point at B, as shown in Fig. 10, the line BV, Fig. 9, can be drawn, and when made the same length as BV, the process can be repeated to VE; and so on until all the points have been connected.

Suppose we have a square stick of timber 12 x 12 inches, and any length, and we wish to make it an octagon; we will first be obliged to find the gauge points so as to mark the stick, to snap a chalk line on it so as to tell how much of the corners must be removed in order to give to the stick eight sides of equal width. We do this as follows: Make a drawing the size of a

section ot the timber, that is, twelve inches square, then draw a line from corner to corner as AB, Fig. 11, and make AC equal in length to AD, which is twelve inches; square over from C to K; set your gauge to BK, and run your lines to this gauge, and remove the corners off to lines, and the stick will then be an octagon having eight equal sides.

There are a number of other methods of finding the

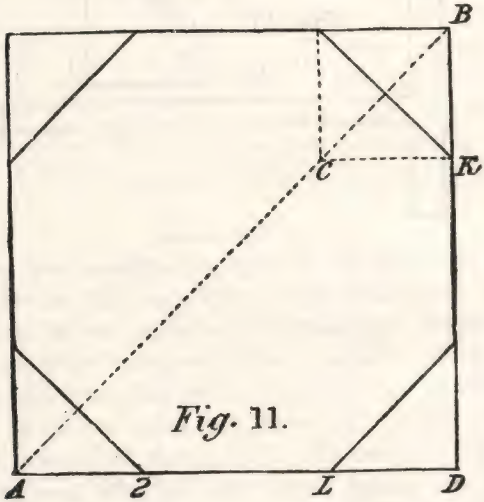


Fig. 11.

gauge points, some of which I may describe further on, but I think I have dwelt long enough on polygons to enable the reader to lay off all the examples given. The polygons not described are so seldom made use of in carpentry, that no authority that I am aware of describes them when writing for the practical workman; though in nearly all works on theoretical geom-

etry the figures are given with all their qualities. If the solution of any of the problems offered in this work requires a description and explanation of polygons with a greater number of sides than eight, such explanation will be given.

CHAPTER III

SOME STRAIGHT LINE SOLUTIONS

The greatest number of difficult problems in carpentry are susceptible of solution by the use of straight lines and a proper application of the steel square, and in this chapter I will endeavor to show the reader how some of the problems may be solved, though it is not intended to offer a treatise on the subject of the utility of the steel square, as that subject has been treated at length in other works, and another and exhaustive work is now in preparation; but it is thought no work on carpentry can be complete without, at least, showing some of the solutions that may be accomplished by the proper use of this wonderful instrument, and this will be done as we proceed.

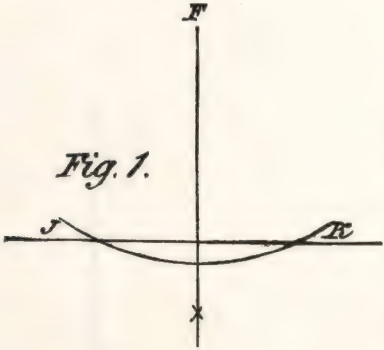


Fig. 1.

One of the most useful problems is one that enables us to make a perpendicular line on any given straight line without the aid of a square. This is obtained as follows: Let JK, Fig. 1, be the given straight line, and make F any point in the square or perpendicular line required. From F with any radius, strike the arc

cutting in JK; with these points as centers, and any radius greater than half JK, make intersection as shown, and from this point draw a line to F, and this line is the perpendicular required. Foundations, and other works on a large scale are often "squared" or laid out by this method, or by another, which I will submit later.

In a previous illustration I showed how to bisect an angle by using the compasses and straight lines, so as to obtain the proper joints or miters for the angles. At Fig. 2, I show how this may be done by the aid of the steel square alone, as follows: The angle is obtuse, and may be that of an octagon or pentagon or other polygon. Mark any two points on the angle, as DN,

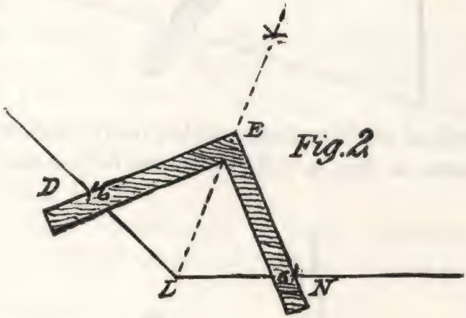


Fig. 2

equally distant from the point of angle L; apply the steel square as shown, keeping the distance EN and ED the same, then a line running through the angle L and the point of the square E will be the line sought.

To bisect an acute angle by the same method, proceed as follows: Mark any two points AC, Fig. 3, equally distant from B; apply the steel square as shown, keeping its sides on AC; then the distance on each side of the square being equal from the corner gives it for a point, through which draw a line from B, and the angle is divided. Both angles shown are divided by the same method, making the intersection

in P the center of the triangle. The main thing to be considered in this solution is to have the distances A and C equal from the point B; also an equal distance from the point or toe of the square to the points of contact C and A on the boundary lines.

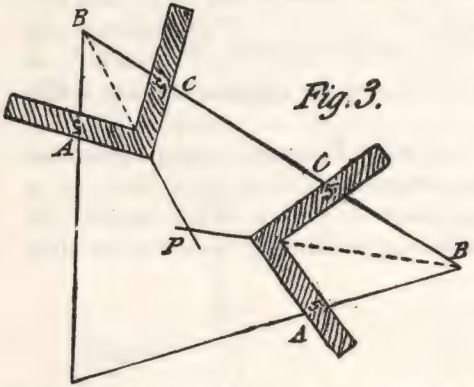


Fig. 3.

A repetition of the same method of bisecting angles, under other conditions, is shown at Fig. 4. The process is just the same, and the

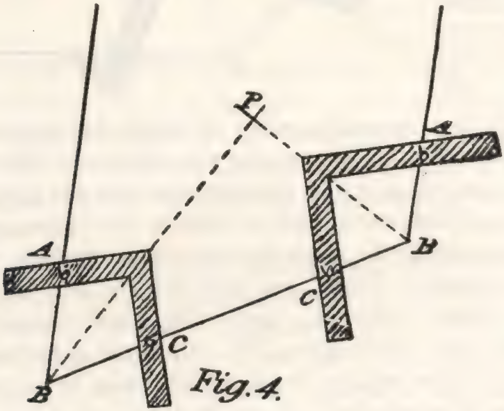


Fig. 4.

reference letters are also the same, so any further explanation is unnecessary.

To get a correct miter cut, or, in other words, an angle of 45°, on a board, make either of the points A or C, Fig. 5, the starting point for the miter, on the edge of the board, then apply the square as shown, keeping the figure 12″ at A or C, as the case may be, with the figure 12″ on the other blade of the square on the edge of the board as shown; then the slopes on the edge of the square from A to B and C to B, will form angles of 45° with the base line AC. This problem is useful from many points of view, and will often suggest itself to the workman in his daily labor.

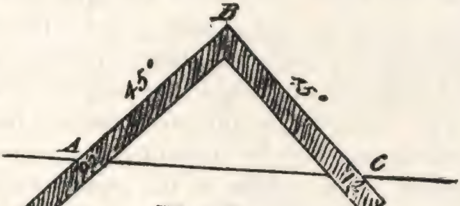


Fig. 5.

To construct a figure showing on one side an angle of 30° and on the other an angle of 60°, by the use of

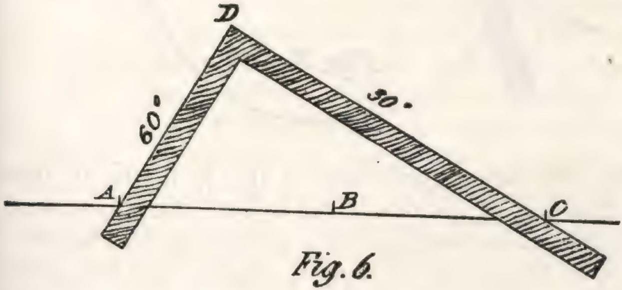


Fig. 6.

the steel square, we go to work as follows: Mark on the edge of a board two equal spaces as AB, BC, Fig. 6, apply the square, keeping its blade on AC and making

AD equal AB; then the angles 30° and 60° are formed as shown. If we make a templet cut exactly as shown in Fig. 5, also a templet cut as shown in this last figure, and these templets are made of some hard wood, we get a pair of set squares for drawing purposes, by which a large number of geometrical problems and drawing kinks may be wrought out.

The diameter of any circle within the range of the steel square may be determined by the instrument as follows: The corner of the square touching any part of the circumference A, Fig. 7, and the blade cutting in points C, B, gives the diameter of the circle as

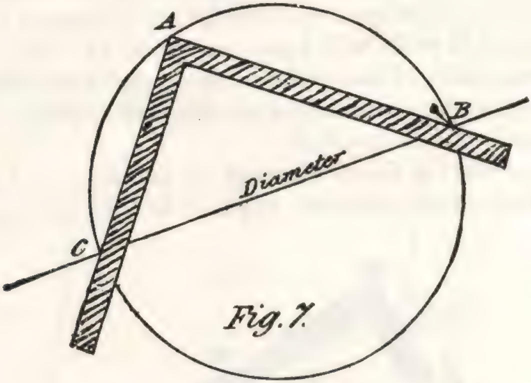


Fig. 7.

shown. Another application of this principle is, that the diameter of a circle being known, the square may be employed to describe the circumference. Suppose CB to be the known diameter; then put in two nails as shown, one at B and the other at C, apply the square, keeping its edges firmly against the nails, continually sliding it around, then the point of the square A will describe half the circumference. Apply the

square to the other side of the nails, and repeat the process, when the whole circle will be described. This problem may be applied to the solution of many others of a similar nature.

At Fig. 8, I show how an equilateral triangle may be obtained by the use of a square. Draw the line

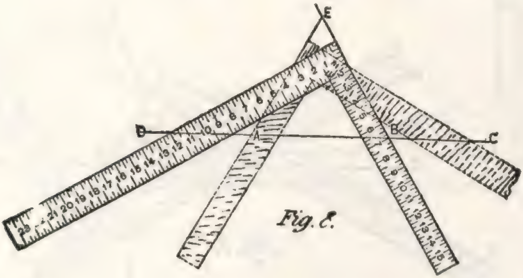


Fig. 8.

DC; take 12 on the blade and 7 on the tongue; mark on the tongue for one side of the figure. Make the distance from D to A equal to the desired length of one side of the figure. Reverse the square, placing it as shown by the dotted lines in the sketch, bringing 7 of the tongue against the point A. Scribe along the tongue, producing the line until it intersects the first line drawn in the point E, then AEB will be an equilateral triangle. A method of describing a hexagon by the square, is shown at Fig. 9, which is quite simple. Draw the line GH; lay off the required length of one side on this line, as DE. Place the square as before, with 12 of the blade and 7 of the tongue against the line GH; placing 7 of the tongue against the point D, scribe along the tongue for the side DC. Place the square as shown by the dotted lines; bringing 7 of the tongue against the point E, scribe the side EF. Con-

tinue in this way until the other half of the figure is drawn. All is shown by FABC.

The manner of bisecting angles has been shown in Figs. 2, 3 and 4 of the present chapter, so that it is not necessary to repeat the process at this time.

The method of describing an octagon by using the square, is shown at Fig. 10. Lay off a square

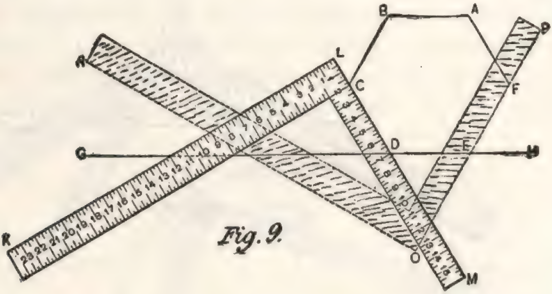


Fig. 9.

section with any length of sides, as AB. Bisect this side and place the square as shown on the side AB, with the length bisected on the blade and tongue; then the tongue cuts the side at the point to gauge for the piece to be removed. To find the size of square required for an octagonal prism, when the side is given: Let CD equal the given side; place the square on the

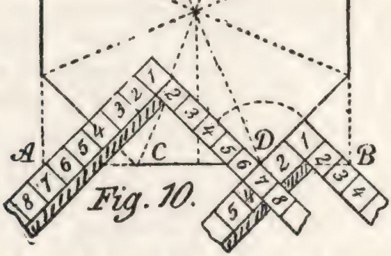
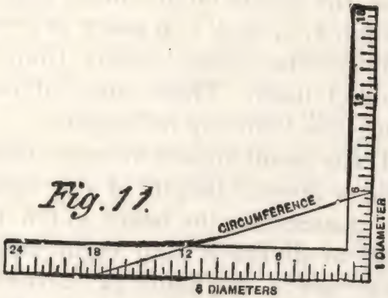


Fig. 10.

line of the side, with one-half of the side on the blade and tongue; then the tongue cuts the line at the point B, which determines the size of the square, and the piece to be removed.

A near approximation to the length or stretch-out of a circumference of a circle may be obtained by the aid of the steel square and a straight line, as follows: Take three diameters of the circle and measure up the side of the blade of the square, as shown at Fig. 11, and fifteen-sixteenths of one diameter on the tongue. From these two points draw a diagonal, and the length of this diagonal will be the length or stretch-out of the circumference nearly.

Fig. 11.



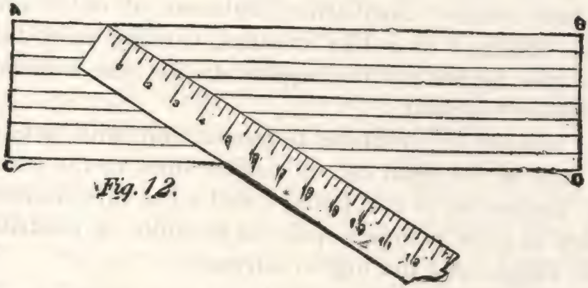


Fig. 12.

If it is desired to divide a board or other substance into any given number of equal parts, without going through the process of calculation, it may readily be done by the aid of the square or even a pocket rule. Let AC, BD, Fig. 12, be the width of the board or

other material, and this width is seven and one-quarter inches, and we wish to divide it into eight equal parts. Lay on the board diagonally, with furthermost point of the square fair with one edge, and the mark 8 on the square on the other edge; then prick off the inches, 1, 2, 3, 4, 5, 6 and 7 as shown, and these points will be the gauge points from which to draw the parallel lines. These lines, of course, will be something less than one inch apart.

If the board should be more than eight inches wide, then a greater length of the square may be used, as for instance, if the board is ten inches wide, and we wish to divide it into eight equal parts, we simply make use of the figure 12 on the square instead of 8, and prick off the spaces every one and a half inches on the square. If the board is more than 12 inches wide, and we require the same number of divisions, we make use of figure 16 on the square, and prick off at every two inches. Any other divisions of the board may be obtained in a like manner, varying only the use of the figures on the square to get the number of divisions required.

As a number of problems in connection with actual work, will be wrought out on similar lines to the foregoing, further on in this book, I will close this chapter in order to give as much space as possible in describing the ellipse and the higher curves.

CHAPTER IV

ELLIPSES, SPIRALS, AND OTHER CURVES

The ellipse, next to the circle, is the curve the carpenter will be confronted with more than any other, and while it is not intended to discuss all, or even a major part, of the properties and characteristics of this curve, I will endeavor to lay before the reader all in connection with it that he may be called upon to deal with.

According to geometricians, an ellipse is a conic section formed by cutting a cone through the curved surface, neither parallel to the base nor making a subcontrary section, so that the ellipse like the circle is a curve that returns within itself, and completely encloses a space. One of the principal and useful properties of the ellipse is, that the rectangle under the two segments of a diameter is as the square of the ordinate. In the circle, the same ratio obtains, but the rectangle under the two segments of the diameter becomes equal to the square of the ordinate.

It is not necessary that we enter into a learned description of the relations of the ellipse to the cone and the cylinder, as the ordinary carpenter may never have any practical use of such knowledge, though, if he have time and inclination, such knowledge would avail him much and tend to broaden his ideas. Suffice for us to show the various methods by which this curve may be obtained, and a few of its applications to actual work.

One of the simplest and most correct methods of describing an ellipse, is by the aid of two pins, a string

and a lead-pencil, as shown at Fig. 1. Let FB be the major or longest axis, or diameter, and DC the minor or shorter axis or diameter, and E and K the two foci

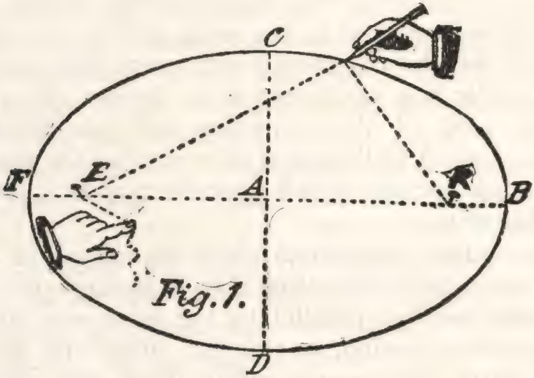


Fig. 1.

These two points are obtained by taking the half of the major axis AB or FA, on the compasses, and. standing one point at D, cut the points E and K on the line FB, and at these points insert the pins at E and K as shown. Take a string as shown by the dotted lines and tie to the pins at K, then stand the pencil at C and run the string round it and carry the string to the pin E, holding it tight and winding it once or twice around the pin, and then holding the string with the finger. Run the pencil around, keeping the loop of the string on the pencil and it will guide the latter in the formation of the curve as shown. When one-half of the ellipse is formed, the string may be used for the other half, commencing the curve at F or B, as the case may be. This is commonly called "a gardener's oval," because gardeners make use of it for forming ornamental beds for flowers, or in making curves for

walks, etc., etc. This method of forming the curve, is based on the well-known property of the ellipse that the sum of any two lines drawn from the foci to their circumference is the same.

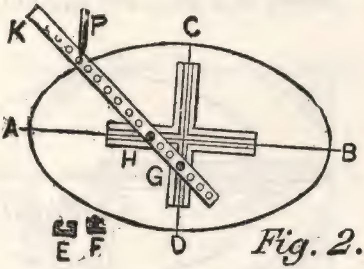


Fig. 2.

Another method of projecting an ellipse is shown at Fig. 2, by using a trammel. This is an instrument consisting of two principal parts, the fixed part in the form of a cross as CD, AB, and the movable tracer HG. The fixed piece is made of two triangular bars or pieces of wood of equal thickness, joined together so as to be in the same plane. On one side of the frame when made, is a groove forming a right-angled cross; the groove is shown in the section at E. In this groove, two studs are fitted to slide easily, the studs having a section same as shown at F. These studs are to carry the tracer and guide it on proper lines. The tracer may have a sliding stud on the end to carry a lead-pencil, or it may have a number of small holes passed through it as shown in the cut, to carry the pencil. To draw an ellipse with this instrument, we measure off half the distance of the major axis from the pencil to the stud G, and half the minor axis from the pencil point to the stud H, then swing the tracer round, and the pencil will describe the ellipse required. The studs have little projections on their tops, that fit easily into the holes in the tracer, but this may be done away with, and two brad awls or pins may be thrust through the tracer and into the studs, and then

proceed with the work. With this instrument an ellipse may easily be described.

Another method, based on the trammel principle, is shown at Figs. 3 and 4, where the steel square is substituted for the instrument shown in Fig. 2. Draw the line AB, bisecting it at right angles, draw CD. Set off these lines the required dimensions of the ellipse to be drawn. Place an ordinary square as shown.

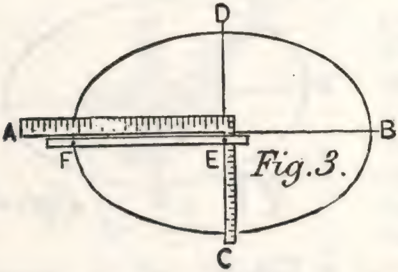


Fig. 3.

Lay the straightedge lengthwise of the figure, as shown in Fig. 3, and putting a pin at E against the square, place the pencil at F, at a point corresponding with the one of the figure. Next place the straightedge, as shown in Fig. 4, crosswise of the figure, and bring the pencil F to a point corresponding to one side of the figure, and set a pin at G. By keeping the two pins E and G against the square,

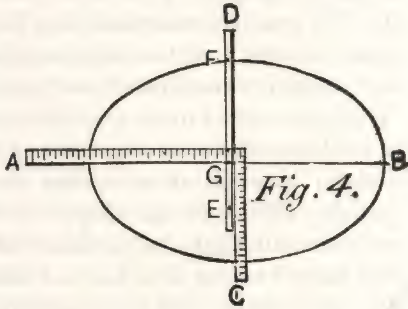


Fig. 4.

and moving the straightedge so as to carry the pencil from side to side, one-quarter of the figure will be struck. By placing the square in the same relative position in each of the other three-quarters, the other parts may be struck.

A method,—and one that is very useful for many purposes,—of drawing an ellipse approximately, is shown in Fig. 5. It is convenient and may be applied to hundreds of purposes, some of which will be illustrated as we proceed. To apply this method, work as follows: First lay off the length of the required figure, as shown by AB, Fig. 5, and the width as shown by CD. Construct a parallelogram that shall have its sides tangent to the figure at the points of its length and width, all as shown by EFGH. Subdivide one-half of the end of the parallelogram into any convenient number of equal parts, as shown at AE, and one-half of its side in the same manner, as shown by ED. Connect these two sets of points by intersecting lines in the manner shown in the engraving. Repeat the operation for each of the other corners of the parallelogram. A line traced through the inner set of intersections will be a very close approximation to an ellipse.

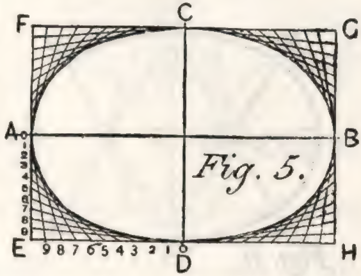


Fig. 5.

There are a number of ways of describing figures that approximate ellipses by using the compasses, some of them being a near approach to a true ellipse, and it is well that the workman should acquaint himself with the methods of their construction. It is only necessary that a few examples be given in this work, as a knowledge of these shown will lead the way to the construction of others when required. The method exhibited in Fig. 6 is, perhaps, the most useful of any employed by workmen, than all other methods com-

bined. To describe it, lay off the length CD, and at right angles to it and bisecting it lay off the width AB. On the larger diameter lay off a space equal to the shorter diameter or width, as shown by DE. Divide the remainder of the length or larger diameter EC into three equal parts; with two of these parts as a radius, and R as a center, strike the circle GSFT. Then, with F as a center and FG as radius, and G as center and GF as radius, strike the arcs as shown, intersecting each other and cutting the line drawn through the shorter diameter at O and P respectively From O, through the points G and F, draw OL and OM, and likewise from P through the same points draw PK and PN. With O as center and OA as radius, strike the arc LM, and with P as center and with like radius, or PB which is the same, strike the arc KN. With F and G as centers, and with FD and CG which are the same, for radii, strike the arcs NM and KL respectively, thus completing the figure. Another method in which the centers for the longer arc are outside the curve lines, is shown at Fig 7. Let AB be the length and CD the breadth; join BD through the center of the line EB, and at

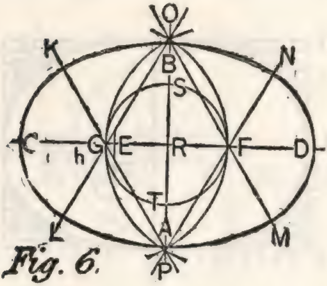


Fig. 6.

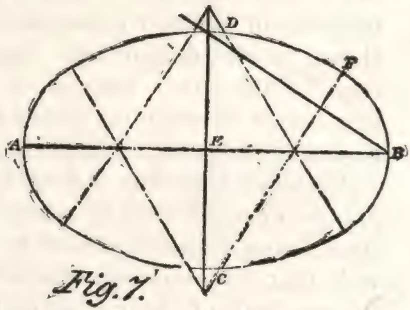


Fig. 7.

right angles to BD draw the line CF indefinitely; then at the points of intersection of the dotted lines will be found the points to describe the required ellipse. A method of describing an ellipse by the intersection of lines is shown at Fig. 8, and which may be applied to any kind of an ellipse with longer or shorter axis. Let WX be the given major axis, and YA the minor axis drawn at right angles to and at the center of each other.

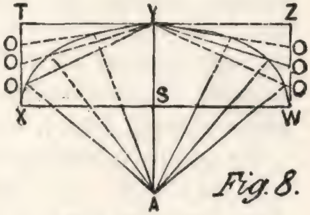


Fig. 8.

Through Y parallel to WX draw ZT, parallel to AY, draw WZ and XT; divide WZ and XT into any number of equal parts, say four, and draw lines from the points

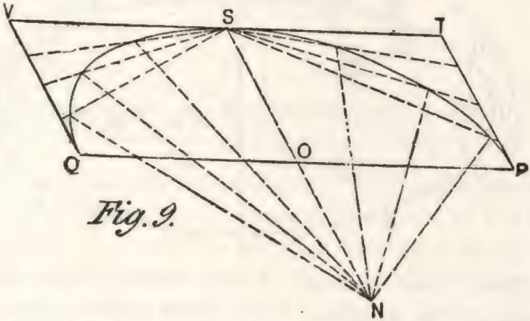


Fig. 9.

of division OOO, etc., to Y. Divide WS and XS each into the same number of equal parts as WZ and XT, and draw lines from A through these last points of division intersecting the lines drawn from OOO, etc., and at these intersections trace the semi-ellipse WYX. The other half of the ellipse may be described in the same manner.

To describe an ellipse from given diameters, by intersection of lines, even though the figure be on a rake: Let SN and QP, Fig. 9, be the given diameters, drawn through the centers of each other at any required angle. Draw QV and PT parallel to SN, through S draw TV parallel to QP. Divide into any number of equal parts PT, QV, PO, and OQ; then proceed as in Fig. 8, and the work is complete

An ellipse may be described by the intersection of arcs as at Fig. 10. Lay off HG and JK as the given axes; then find the foci as described in Fig. 1. Between L and L and the center M mark any number of points at pleasure as 1, 2, 3, 4. Upon L and L with H1 for radius describe arcs at O, O, O, O; upon L and with C1 for radius describe intersecting arcs at O, O, O, and

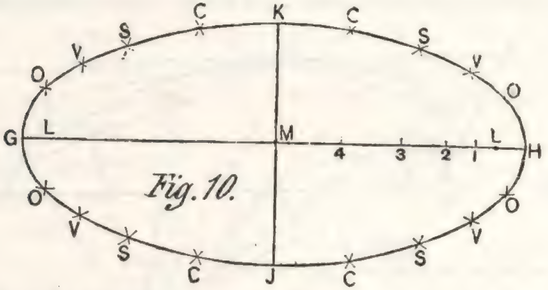


Fig. 10.

O; then these points of intersection will be in the curve of the ellipse. The other points V, S, C, are found in the same manner, as follows: For the point V take H2 for one radius, and G2 for the other; S is found by taking H3 for one radius, and G3 for the other; C is found in like manner, with H4 for one radius, and G4 for the last radius, using the foci for centers as at first. Trace a curve through the points H, O, V, S, C. K, etc., to complete the ellipse

It frequently happens that the carpenter has to make

the radial lines for the masons to get their arches in proper form, as well as making the centers for the same, and, as the obtaining of such lines for elliptical work is very tedious, I illustrate a device that may be employed that will obviate a great deal of labor in producing such lines. The instrument and the method of using it is exhibited at Fig. 11 and marked Ee. The semi-ellipse HI, or xx, may be described with a string or strings, the outer line being described by use of a string fastened to the foci F and D, with the extreme point at E; and the inner line, with the string being fastened at A and B, with the pencil point in the tightened string at O. The sectional line LKJ shows the center of the arch, and the lines SSS are at

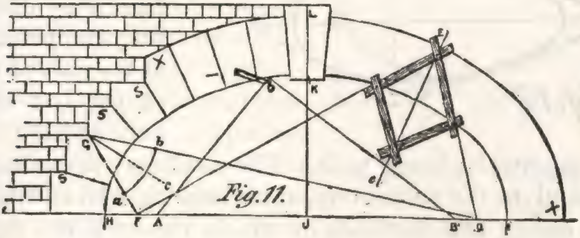


Fig. 11.

right angles with this vertical line. The usual method of finding the normal by geometry is shown at GABC, but the more practical method of finding it is by the use of the instrument, where Ee shows the normal. I believe the device is of French origin, and I give a translation of a description and use of the instrument: "It is made of four pieces of lath or metal put together so as to form a perfect rectangle and having its joints loose, as shown in the diagram. Considering that the most perfect elliptical curve is that described by a string from the foci (foyer) of the ellipse, draw the profiles of the extrados and intrados, as shown in Fig. 11, where your joints are to be, then take your

string, draw it to the point marked as at E, adjust two sides of your instrument to correspond with the lines of the string, then, from the point marked, draw a line passing through the two angles, E and e, and the line Ee will be the normal or the radial line sought."

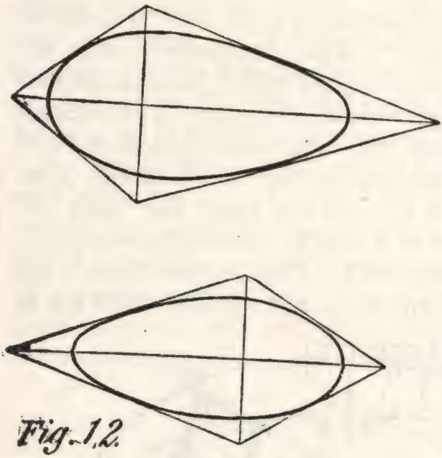


Fig. 12.

The oval is not an ellipse, nor are any of the figures obtained by using the compasses, as no part of an ellipse is a circle, though it may approach closely to it. The oval may sometimes be useful to the carpenter, and it may be well to illustrate one or two methods by which these figures may be described.

Let us describe a diamond or lozenge-shaped figure, such as shown at Fig. 12, and then trace a curve inside of it as shown, touching the four sides of the figure, and a beautiful egg-shaped curve will be formed. For effect we may elongate the lozenge or shorten it at will, placing the short diameter at any point. This form of oval is much used by turners and lathe men generally, in the formation of pillars, balusters, newel-posts and turned ornamental work generally.

An egg-shaped oval may also be inscribed in a figure having two unequal but parallel sides, both of which

are bisected by the same line, perpendicular to both as shown in Fig. 13. These few examples are quite sufficient to satisfy the requirements of the workman, as they give the key by which he may construct any oval he may ever be called upon to form.

I have dwelt rather lengthily on the subject of the ellipse because of its being rather difficult for the workman to deal with, and it is meet he should acquire a fair knowledge of the methods of constructing it. It is not my province to enter into all the details of the properties of this very intersecting figure, as the workman can find many of these in any good work on mensuration, if he should require more. I may say here, however, that geometricians so far have failed to discover any scientific method of forming parallel ellipses, so that while the inside or outside lines of an ellipse can be obtained by any of the methods I have given, the parallel line must be obtained either by gauging the width of the material or space required, or must be obtained by "pricking off" with compasses or other aid. I thought it best to mention this as many a young man has spent hours in trying to solve the unsolvable problem when using the pins, pencil and string.

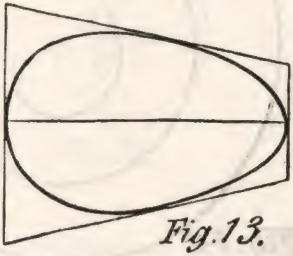


Fig. 13.

There are a number of other curves the carpenter will sometimes meet in daily work, chief among these being the scroll or spiral, so it will be well for him to have some little knowledge of its structure. A true spiral can be drawn by unwinding a piece of string that

has been wrapped around a cone, and this is probably the method adopted by the ancients in the formation of the beautiful Ionic spirals they produced. A spiral drawn by this method is shown at Fig. 14. This was formed by using two lead-pencils which had been sharpened by one of those patent sharpeners and which gave them the shape seen in Fig. 15. A piece of string was then tied tightly around the pencil, and one end was wound round the conical end, so as to lie in notches made in one of the pencils; the point of a second pencil was pierced through the string at a convenient point near the first pencil, completing the arrangement shown in Fig. 15. To draw the spiral the pencils must be kept vertical, the point of the first being held firmly in the hole of the spiral, and the second pencil must then be carried around the first, the distance between the two increasing regularly, of course, as the string unwinds.

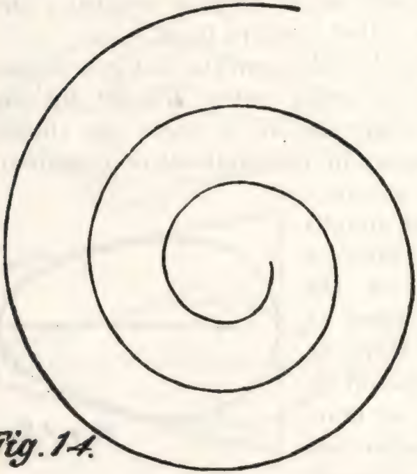


Fig. 14.

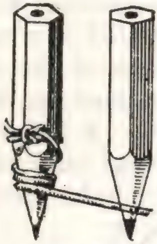


Fig. 15.

This is a rough-and-ready apparatus, but a true

spiral can be described by it in a very few minutes. By means of a larger cone, spirals of any size can, of course, be drawn, and that portion of the spiral can be used which conforms to the required height.

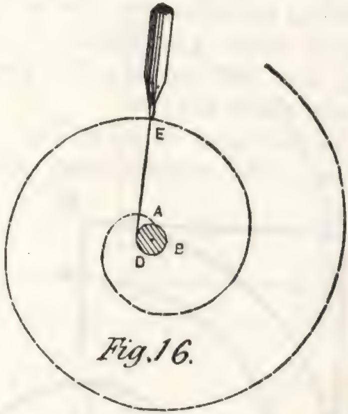


Fig. 16.

Another similar method is shown in Fig. 16, only in this case the string unwinds from a spool on a fixed center A, D, B. Make loop E in the end of the thread, in which place a pencil as shown. Hold the spool firmly and move the pencil around it, unwinding the thread. A curve will be described, as shown in the lines. It is evident that the proportions of the figure are determined by the size of the spool. Hence a larger or smaller spool is to be used, as circumstances require.

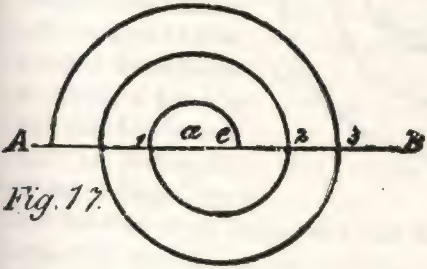


Fig. 17.

A simple method of forming a figure that corresponds to the spiral somewhat, is shown in Fig. 17. This is drawn from two centers only, a and e, and if the distance between these centers is not too great, a fairly smooth appearance will be given to the figure. The method

of describing is simple. Take a1 as radius and describe a semi-circle; then take e1 and describe semi-circle 12 on the lower side of the line AB. Then with a2 as radius describe semi-circle above the line; again, with e3 as radius, describe semi-circle below the line AB; lastly with a3 as radius describe semi-circle above the line.

In the spiral shown at Fig. 18 we have one drawn in a scientific manner, and which can be formed to dimensions. To draw it, proceed as follows: Let BA be the given breadth, and the number of revolutions, say one and three-fourths; now multiply one and three-fourths by four, which equals seven; to which add three, the number of times a side of a square is contained in the diameter of the eye, making ten in all. Now divide AB into ten equal parts and set one from A to D, making eleven parts. Divide DB into two equal parts at O, then OB will be the radius of the first quarter OF, FE; make the side of the square, as shown at GF, equal to one of the eleven parts, and divide the number of parts obtained by multiplying the revolutions by four, which is seven; make the

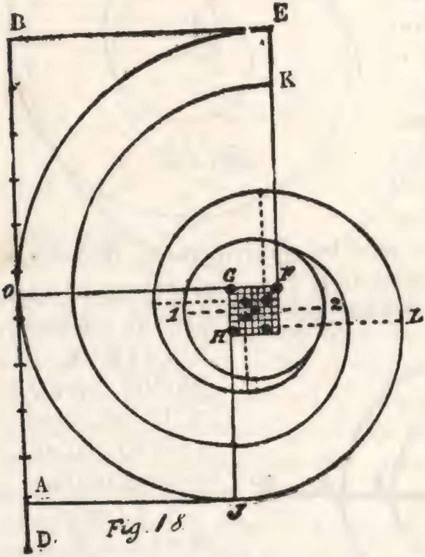


Fig. 18

diameter of the eye, 12, equal to three of the eleven parts. With F as a center and E as a radius make the quarter EO; then, with G as a center, and GO as a radius, mark the quarter OJ. Take the next center at H and HJL in the quarter; so keep on for centers, dropping one part each time as shown by the dotted angles. Let EK be any width desired, and carry it around on the same centers.

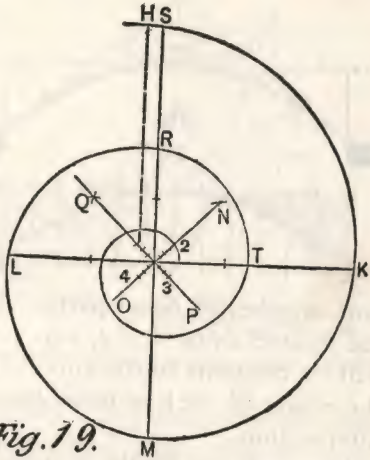


Fig. 19.

Another method of obtaining a spiral by arcs of circles is shown at Fig. 19, which may be confined to given dimensions. Proceed as follows: Draw SM and LK at right angles; at the intersection of these lines bisect the angles by the lines NO and QP; and on NO and QP from the intersection each way set off three equal parts as shown. On 1 as center and 1H as radius, describe the arc HK, on 2 describe the arc KM, on 3 describe the arc ML, on 4 describe the arc LR. The fifth center to describe the arc RT is under 1 on the line QP; and so proceed to complete the curve.

There are a few other curves that may occasionally prove useful to the workman, and I submit an example or two of each in order that, should occasion arise where such a curve or curves are required, they may be met with a certain amount of knowledge of the subject.

The first is the parabola, a curve sometimes used in bridge work or similar construction. Two examples of the curve are shown at Fig. 20, and the methods of describing them. The upper one is drawn as follows:

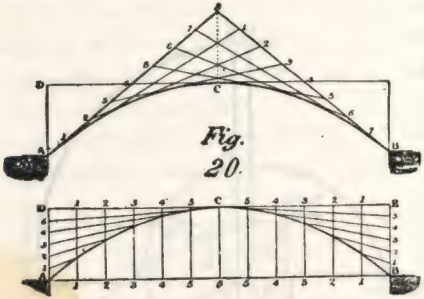


Fig. 20.

1. Draw C8 perpendicular to AB, and make it equal to AD.

Next, join A8 and B8, and divide both lines into the same number of equal parts, say 8; number them as in the figure; draw 1, 1-2, 2-3, 3, etc., then these lines will be tangents to the curve; trace the curve to touch the center of each of those lines between the points of intersection.

The lower example is described thus: 1. Divide AD and BE, into any number of equal parts; CD and CE into a similar number.

2. Draw 1, 1-2, 2, etc., parallel to AD, and from the points of division in AD and BE, draw lines to C. The points of intersection of the respective lines are points in the curve.

The curves found, as in these figures, are quicker at the crown than a true circular segment; but, where the rise of the arch is not more than one-tenth of the span, the variation cannot be perceived.

A raking example of this curve is shown in Fig. 21, and the method of describing it: Let AC be the ordinate or vertical line, and DB the axis, and B its vertex; produce the axis to E, and make BE equal to DB; join EC, EA, and divide them each into the same number

of equal parts, and number the divisions as shown on the figures. Join the corresponding divisions by the lines 11, 22, etc., and their intersections will produce the contour of the curve.

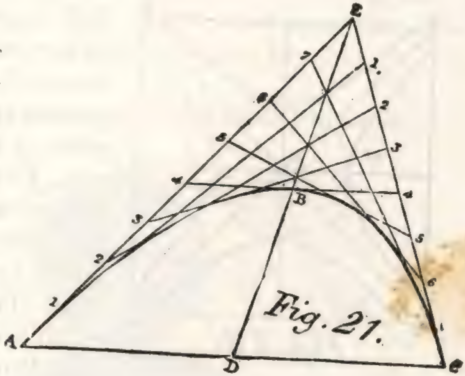


Fig. 21.

The hyperbola is somewhat similar in appearance to the parabola but it has properties peculiar to itself. It is a figure not much used in carpentry, but it may be well to refer to it briefly: Suppose there be two right equal cones, Fig. 22, having the same axis, and cut by a plane Mm, Nm, parallel to that axis, the sections MAN, mna, which result, are hyperbolas. In place of two cones opposite to each other, geometricians sometimes suppose four cones, which join on the lines EH, GB, Fig. 23, and of which axis form two right lines, Ff, F'f', crossing the center C in the same plane.

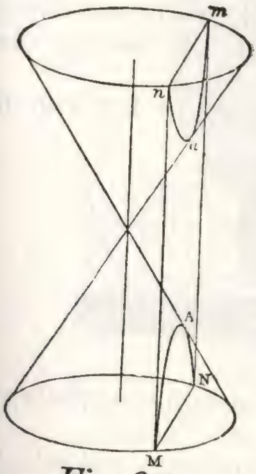


Fig. 22.

To describe a cycloid: The cycloid is the curve described by a point in the circumference of a circle rolling on a straight line, and is described as follows:

1. Let GH, Fig. 24, be the edge of a straight ruler, and C the center of the generating circle.

2. Through C draw the diameter AB perpendicular to GH, and EF parallel to GH; then AB is the height of the curve, and EF is the place of the center of the generating circle at every point of its progress.

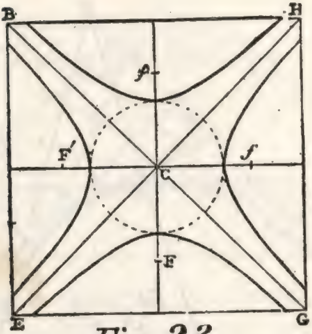


Fig. 23.

3. Divide the semi-circumference from B to A into any number of equal parts, say 8, and from A draw chords to the points of division.

4. From C, with a space in the dividers equal to one of the divisions on the circle, step off on each side the same number of spaces as the semi-circumference is divided into, and through the points draw perpendiculars to GH; number them as in the diagram.

5. From the points of division in EF with the

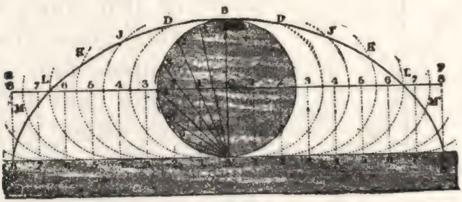


Fig. 24.

radius of the generating circle, describe indefinite arcs as shown by the dotted lines.

6. Take the chord A1 in the dividers, and with the foot at 1 and 1 on the line GH, cut the indefinite arcs

described from 1 and 1 respectively at D and D′, then D and D′ are points in the curve.

7. With the chord A2, from 2 and 2 in GH, cut the indefinite arcs in J and J′, with the chord A3, from 3 and 3, cut the arcs in K and K′ and apply the other chords in the same manner, cutting the arcs in LM, etc.

8. Through the points so found trace the curve.

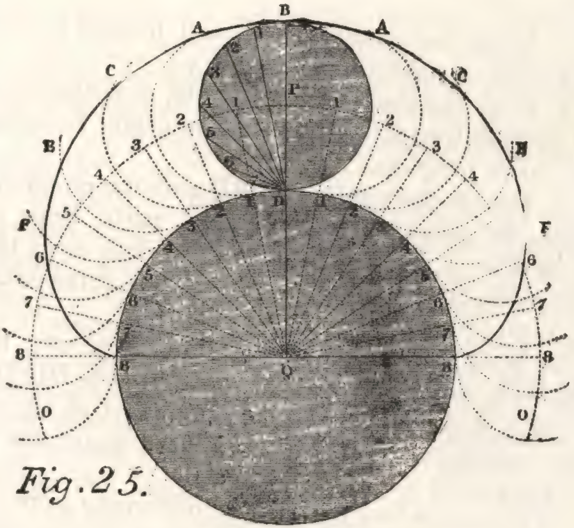


Fig. 25.

Each of the indefinite arcs in the diagram represents the circle at that point of its revolution, and the points D, J, K, etc., the position of the generating point B at each place. This curve is frequently used for the arches of bridges, its proportions are always constant, viz.: the span is equal to the circumference of the generating circle and the rise equal to the diameter. Cycloidal arches are frequently constructed which are

not true cycloids, but approach that curve in a greater or less degree.

The epicycloidal curve is formed by the revolution of a circle round a circle, either within or without its circumference, and described by a point B, Fig. 25, in the circumference of the revolving circle, and Q of the stationary circle.

The method of finding the points in the curve is here given:

1. Draw the diameter 8, 8 and from Q the center, draw QB at right angles to 8, 8.

2. With the distance QP from Q, describe an arc O, O representing the position of the center P throughout its entire progress.

3. Divide the semi-circle BD and the quadrants D8 into the same number of equal parts, draw chords from D to 1, 2, 3, etc., and from Q draw lines through the divisions in D8 to intersect the curve OO in 1, 2, 3, etc.

4. With the radius of P from 1, 2, 3, etc., in OO, describe indefinite arcs; apply the chords D1, D2, etc. from 1, 2, 3, etc., in the circumference of Q, cutting the indefinite arcs in A, C, E, F, etc., which are points in the curve.

We are now in a position to undertake actual work, and in the next chapter, I will endeavor to apply a part of what has preceded to practical examples, such as are required for every-day use. Enough geometry has been given to enable the workman, when he has mastered it all, to lay out any geometrical figure he may be called upon to execute; and with, perhaps, the exception of circular and elliptical stairs and hand-railings, which require a separate study, by what has been formulated and what will follow, he should be able to execute almost any work in a scientific manner.

PART II

PRACTICAL EXAMPLES

CHAPTER I

We are now in a position to undertake the solution of practical examples, and I will commence this department by offering a few practical solutions that will bring into use some of the work already known to the student, if he has followed closely what has been presented.

It is a part of the carpenter's duty to lay out and construct all the wooden centers required by the bricklayer and mason for turning arches over openings of all kinds; therefore, it is essential he should know as much concerning arches as will enable him to attack the problems with intelligence. I have said something of arches, in Part I, but not sufficient to satisfy all the needs of the carpenter, so I supplement with the following on the same subject: Arches used in building are named according to their curves,—circular, elliptic, cycloid, parabolic, hyperbolic, etc. Arches are also known as three or four centered arches. Pointed arches are called lancet, equilateral and depressed. Voussoirs is the name given to the stones forming the arch; the central stone is called the keystone. The highest point in an arch is called the crown, the lowest the springing line, and the spaces between the crown and springing line on either side, the haunches or flanks. The under, or concave, sur-

face of an arch is called the intrados or soffit, the upper or convex surface is called the extrados. The span of an arch is the width of the opening The supports of an arch are called abutments, piers, or

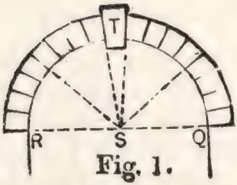


Fig. 1.

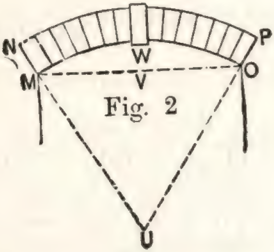


Fig. 2

springing walls. This applies to the centers of wood, as well as to brick, stone or cement. The following six illustrations show the manner of getting the curves, as well as obtaining the radiating lines, which, as a rule, the carpenter will be asked to prepare for the mason. We take them in the following order:

Fig. 1. A Semi-circular Arch.—RQ is the span, and the line RQ is the springing line; S is the center from

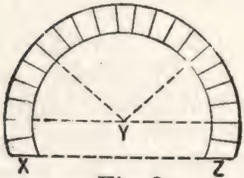


Fig. 3.

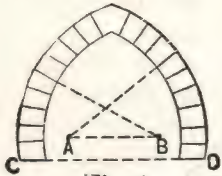


Fig. 4.

which the arch is described, and to which all joints of the voussoirs tend. T is the keystone of the arch.

Fig. 2. A Segment Arch.—U is the center from which the arch is described, and from U radiate all

the joints of the arch stones. The bed line of the arch OP or MN is called by mason builders a skew-back. OM is the span, and VW is the height or versed sine of the segment arch.

Figs. 3 and 4. Moorish or Saracenic Arches, one of which is pointed. Fig. 3 is sometimes called the horseshoe arch. The springing lines DC and ZX of both arches are below the centers BA and Y.

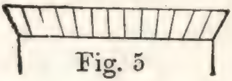


Fig. 5

Fig. 5. A Form of Lintol Called a Platband, built in this form as a substitute for a segment arch over the opening of doors or windows, generally of brick, wedge-shaped.

Fig. 6. The Elliptic Arch.—This arch is most perfect when described with the trammel, and in that case

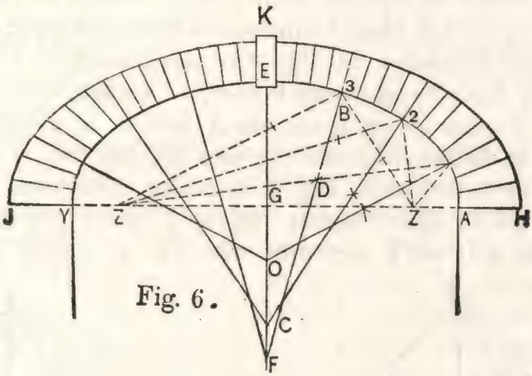


Fig. 6.

the joints of the arch stones are found as follows: Let ZZ be the foci, and B a point on the intrados where a joint is required; from ZZ draw lines to B, bisect the angle at B by a line drawn through the intersecting arcs D produced for the joint to F. Joints at 1 and 2

are found in the same manner. The joints for the opposite side of the arch may be transferred as shown. The semi-axes of the ellipse, HG, GK, are in the same ratio as GE to GA. The voussoirs near the springing

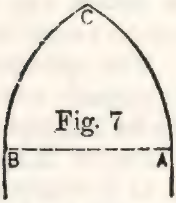


Fig. 7

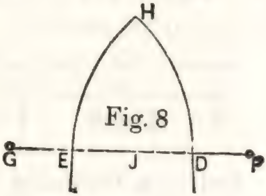


Fig. 8

line of the arch are thus increased in size for greater strength. I gave a very good description of this latter arch in Part I, which see.

Another series of arches, known as Gothic arches, are shown as follows, with all the centers of the curve given, so that their formation is rendered quite simple. The arch shown at Fig. 7 is equilateral and its outlines have been shown before. I repeat, however, let AB be the given span; on A and B as centers with AB as radius, describe the arcs AC and BC.

The lancet arch, Fig. 8, is drawn as follows: DE is the given span; bisect DE in J, make DF and EG equal DJ; on F as center with FE as radius describe

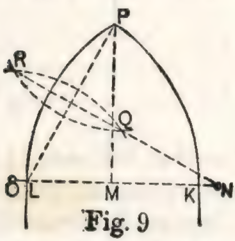


Fig. 9

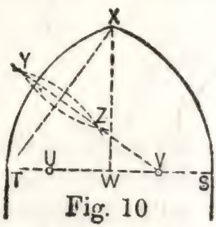


Fig. 10

the arc EH, and on G as center describe the arc DH.

A lancet arch, not so acute as the previous one, is

shown at Fig. 9. Let KL be the given span; bisect KL in M; make MP at right angles to KL and of the required height; connect LP, bisect LP by a line through the arcs R, Q produced to N; make MO equal MN; with N and O as centers, with NL for radius describe the arcs KP and LP. Fig. 10 shows a low or drop arch, and is obtained as follows: Let ST be the given span, bisect ST in W; let WX be the required height at right angles to TS; connect TX,

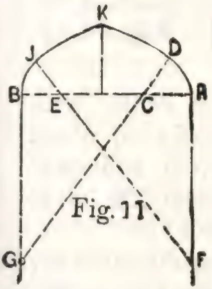


Fig. 11

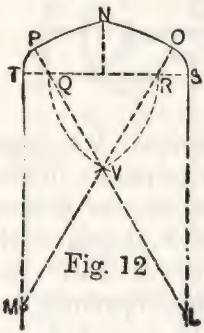


Fig. 12

bisect TX by a line through the arcs YZ produced to V, make TU equal SV; on V and U as centers with VT as radius describe the arcs TX and SX. Another Gothic arch with a still less height is shown at Fig. 11. Suppose AB to be the given span; then divide AB into four equal parts; make AF and BG equal AB, connect FE and produce to D; with CA as radius, on C and E, describe the arcs AD and BK; on F and G as centers, describe the arcs JK and DK.

Another four-centered arch of less height is shown at Fig. 12. Let SI be the given span, divide into six equal parts; on R and Q as centers with RQ as radius describe the arcs QV and RV, connect QV and RV and produce to L and M; on R and Q as centers with QT as

radius describe the arcs TP and SO; on L and M as centers describe the arcs PN and ON.

To describe an equilateral Ogee arch, like Fig. 13, proceed as follows: Make **YZ** the given span; make

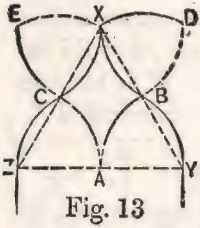


Fig. 13

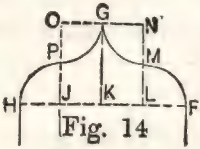


Fig. 14

YX equal YZ, bisect **YZ** in A; on A as center with AY as radius describe the arcs YB and ZC; on B and X as centers describe the arcs BD and XD, and on C and X as centers describe the arcs CE and XE, on E and D as centers describe the arcs BX and CX.

Fig. 14 shows the method of obtaining the lines for an Ogee arch, having a height equal to half the span. Suppose FH to be the span, divide into four equal parts, and at each of the points of division draw lines LN, KG and JO at right angles to FH; with LF for radius on L and J describe the quarter circles FM and HP; and with the same radius on O and N describe the quarter circles PG and MG.

These examples—all or any of them—can be made use of in a great number of instances. Half of the Ogee curve is often employed for veranda rafters, as for the roofs of bay-windows, for tower roofs and for bell cases, for oriel and bay-windows, and many other pieces of work the carpenter will be confronted with from time to time. They also have value as aids in forming mouldings and other ornamental work, as for

example Fig. 15, which shows a moulding for a base or other like purpose. It is described as follows: Draw AB; divide it into five equal parts; make CD equal to four of these. Through D draw DF parallel with AB. From D, with DC as radius, draw the arc CE. Make EF equal to DE; divide EF into five parts; make the line above F equal to one of these; draw FG equal to six of these. From G, with radius DE, describe the arc; bisect GF, and lay the distance to H. It is the center of the curve, meeting the semi-circle described from M. Join NO, OS, and the moulding is complete.

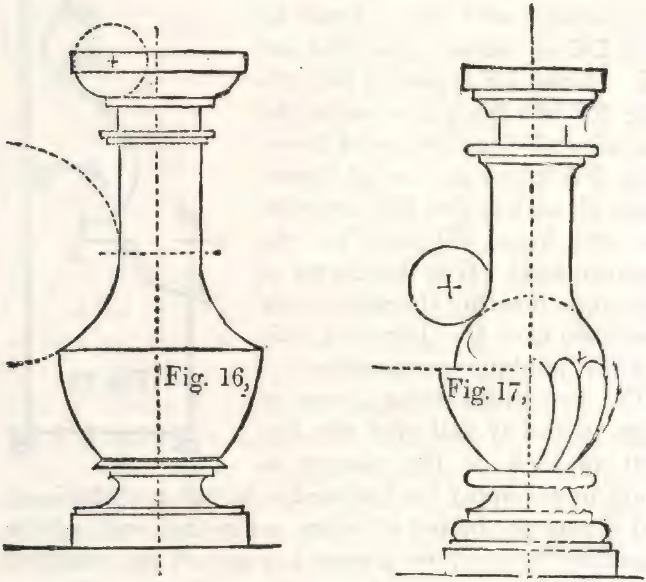
Fig. 15

The two illustrations shown at Figs. 16 and 17 will give the student an idea of the manner in which he can apply the knowledge he has now obtained, and it may not be out of place to say that with a little ingenuity he can form almost any sort of an ornament he wishes by using this knowledge. The two illustrations require no explanation as their formation is self evident. Newel posts, balusters, pedestals and other turned or wrought ornaments, may be designed easily if a little thought be brought to bear on the subject.

The steel square is a great aid in working out problems in carpentry, and I will endeavor to show, as briefly as possible, how the square can be applied to some difficult problems, and insure correct solutions.

It is unnecessary to give a full and complete description of the steel square. Every carpenter and joiner is

supposed to be the possessor of one of these useful tools, and to have some knowledge of using it. It is not everyone, however, who thoroughly understands its powers or knows how to employ it in solving all



the difficulties of framing, or to take advantage of its capabilities in laying out work. While it is not my intention to go deeply into this subject in this volume, as that would lengthen it out to unreasonable limits, so it must be left for a separate work, yet there are some simple things connected with the steel square, that I think every carpenter and joiner should know, no matter whether he intends to go deeper into this study of the steel square or not. One of these things is the learning to read the tool. Strange as it may

appear, not over one in fifty of those who use the square are able to read it, or in other words, able to explain the meaning and uses of the figures stamped on its two sides. The following will assist the young fellows who want to master the subject.

The square consists of two arms, at right angles to each other, one of which is called the blade and which is two feet long, and generally two inches wide. The other arm is called the tongue, and may be any length from twelve to eighteen inches, and 1¼ to 2 inches in width. The best square has always a blade 2 inches wide. Squares made by firms of repute are generally perfect and require no adjusting or "squaring."

The lines and figures formed on squares of different make sometimes vary, both as to their position on the square and their mode of application, but a thorough understanding of the application of the scales and lines shown on any first-class tool, will enable the student to comprehend the use of the lines and figures exhibited on any good square.

It is supposed the reader understands the ordinary divisions and subdivisions of the foot and inch into twelfths, inches, halves, quarters, eighths and sixteenths, and that he also understands how to use that part of the square that is subdivided into twelfths of an inch. This being conceded, we now proceed to describe the various rules as shown on all good squares. Sometimes the inch is subdivided into thirty-seconds, in which the subdivision is very fine, but this scale will be found very convenient in the measurement of drawings which are made to a scale of half, quarter, one-eighth or one-sixteenth of an inch to a foot.

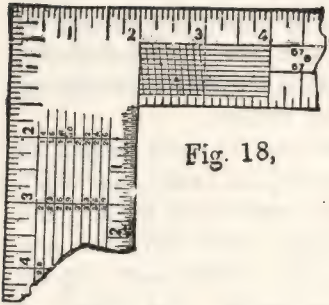


Fig. 18,

In the illustration Fig. 18, will be noticed a series of lines extending from the junction of the blade and tongue to the four-inch limit. From the figures 2 to 3 these lines are crossed by diagonal lines. This figure, reaching from 2 to 4, is called a diagonal scale, and is intended for taking off hundredths of an inch The

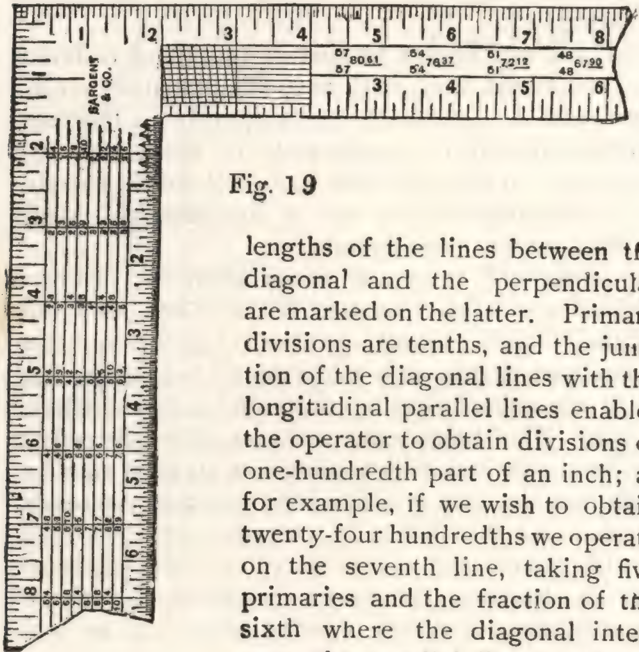


Fig. 19

lengths of the lines between the diagonal and the perpendicular are marked on the latter. Primary divisions are tenths, and the junction of the diagonal lines with the longitudinal parallel lines enables the operator to obtain divisions of one-hundredth part of an inch; as for example, if we wish to obtain twenty-four hundredths we operate on the seventh line, taking five primaries and the fraction of the sixth where the diagonal intersects the parallel line, as shown

by the "dots" on the compasses, and this gives us the distance required.

The use of the scale is obvious, and needs no furtner explanation, as the dots or points are shown.

The lines of figures running across the blade of the square, as shown in Fig. 19, forms what is a very convenient rule for determining the amount of material in length or width of stuff. To use it proceed as follows: If we examine we will find under the figure 12, on the outer edge of the blade, where the length of the boards, plank or scantling to be measured is given, and the answer in feet and inches is found under the inches in width that the board, etc., measures. For example, take a board nine feet long and five inches wide, then under the figure 12, on the second line, will be found the figure 9, which is the length of the board; then run along this line to the figure directly under the five inches (the width of the board) and we find three feet nine inches, which is the correct answer in ' board measure." If the stuff is three inches thick it is trebled, etc., etc. If the stuff is longer than any figures shown on the square it can be measured as above and doubling the result. This rule is calculated, as its name indicates, for board measure, or for surfaces 1 inch in thickness. It may be advantageously used, however, upon timber by multiplying the result of the face measure of one side of a piece by its depth in inches. To illustrate, suppose it be required to measure a piece 25 feet long, 10x14 inches in size. For the length we will take 12 and 13 feet. For the width we will take 10 inches, and multiply the result by 14. By the rule a board 12 feet long and 10 inches wide contains 10 feet, and one 13 feet long and 10 inches wide, 10 feet 10 inches. Therefore, a board 25 feet long and 10 inches wide must contain 20 feet and

10 inches. In the timber above described, however, we have what is equivalent to 14 such boards, and therefore we multiply this result by 14, which gives 291 feet and 8 inches the board measure.

Along the tongue of the square following the diagonal scale is the brace rule, which is a very simple and very convenient method of determining the length of any brace of regular run. The length of any brace simply represents the hypothenuse of a right-angled triangle. To find the hypothenuse extract the square root of the sum of the squares of the perpendicular and horizontal runs. For instance, if 6 feet is the horizontal run and 8 feet the perpendicular, 6 squared equals 36, 8 squared equals 64; 36 plus 64 equals 100, the square root of which is 10. These are the rules generally used for squaring the frame of a building.

If the run is 42 inches. 42 squared is 1764, double that amount, both sides being equal, gives 3528, the square root of which is, in feet and inches, 4 feet 11.40 inches.

In cutting braces always allow in length from a sixteenth to an eighth of an inch more than the exact measurement calls for.

Directly under the half-inch marks on the outer edge of the back of the tongue, Fig. 19, will be noticed two figures, one above the other. These represent the run of the brace, or the length of two sides of a right-angled triangle; the figures immediately to the right represent the length of the brace or the hypothenuse. For instance, the figures $\frac{57}{57}$, and 80.61 show that the run on the post and beam is 57 inches, and the length of the brace is 80.61 inches.

Upon some squares will be found brace measurements given, where the run is not equal, as $\frac{18}{24}$.30. It will be noticed that the last set of figures are each just

three times those mentioned in the set that are usually used in squaring a building. So if the student or mechanic will fix in his mind the measurements of a few runs, wich the length of braces, he can readily work almost any length required.

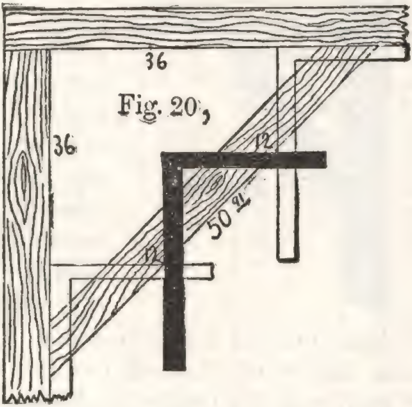


Fig. 20.

Take a run, for instance, of 9 inches on the beam and 12 inches on the post. The length of brace is 15 inches. In a run, therefore, of 12, 16, 20, or any number of times above the figures, the length of the brace will bear the same proportion to the run as the multiple used. Thus if you multiply all the figures by 3 you will have 36 and 48 inches for the run, and 60 inches for the brace, or to remember still more easily, 3, 4 and 5 feet.

There is still another and an easier method of obtaining the lengths of braces by aid of the square, also the bevels as may be seen in Fig. 20, where the run is 3 feet, or 36 inches, as marked. The length and bevels of the brace are found by applying the square three times in the position as shown; placing 12 and 12 on the edge of the timber each time. By this method both length and bevel are obtained with the least amount of labor. Braces having irregular runs may be oberated in the same manner. For instance, suppose we wish to set in a brace where the run is 4 feet and 3 feet; we simply take 9 inches on the

tongue and 12 inches on the blade and apply the square four times, as shown in Fig. 21, where the brace is given in position. Here we get both the proper length and the exact bevels. It is evident from this that braces, regular or irregular, and of any length, may be obtained with bevels for same by this method, only care must be taken in adopting the figures for the purpose.

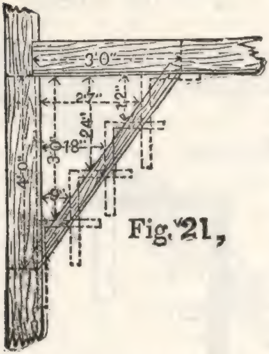


Fig. 21,

If we want a brace with a two-foot run and a four-foot run, it must be evident that as two is the half of four, so on the square take 12 inches on the tongue, and 6 inches on the blade, apply four times and we have the length and the bevels of a brace for this run.

For a three-by-four foot run take 12 inches on the tongue and 9 inches on the blade, and apply four times, because as 3 feet is ¾ of four feet, so 9 inches is ¾ of 12 inches.

While on the subject of braces I submit the following table for determining the length of braces for any run from six inches to fourteen feet. This table has been carefully prepared and may be depended upon as giving correct measurements. Where the runs are regular or equal the bevel will always be a miter or angle of 45°, providing always the angle which the brace is to occupy is a right angle—a "square." If the run is not equal, or the angle not a right angle, then the bevels or "cuts" will not be miters, and will have to be obtained either by taking figures on the square or by a scaled diagram.

TABLE

Length of Run ft. in.	ft. in.	Length of Brace ft. in.	Length of Run ft. in.	ft. in.	Length of Brace ft. in.
6 ×	6 =	8.48	4 3 ×	4 3 =	6 0.12
6 ×	9 =	10.81	4 3 ×	4 6 =	6 2.27
9 ×	9 =	1 0.72	4 3 ×	4 9 =	6 4.49
1 0 ×	1 0 =	1 4.97	4 3 ×	5 0 =	6 6.74
1 0 ×	1 3 =	1 7.20	4 6 ×	4 6 =	6 4.36
1 3 ×	1 3 =	1 9.23	4 6 ×	4 9 =	6 6.51
1 3 ×	1 6 =	1 11.43	4 6 ×	5 0 =	6 8.72
1 6 ×	1 6 =	2 1.45	4 9 ×	4 9 =	6 8.61
1 6 ×	1 9 =	2 3.65	4 9 ×	5 0 =	6 10.75
1 9 ×	1 9 =	2 5.69	5 0 ×	5 0 =	7 0.85
1 9 ×	2 0 =	2 7.89	5 3 ×	5 3 =	7 5.09
2 0 ×	2 0 =	2 9.94	5 6 ×	5 6 =	7 9.33
2 0 ×	2 3 =	3 0.12	5 9 ×	5 9 =	8 1.58
2 0 ×	2 6 =	3 2.41	6 0 ×	6 0 =	8 5.82
2 3 ×	2 6 =	3 4.36	6 3 ×	6 3 =	8 10.06
2 6 ×	2 6 =	3 6.42	6 6 ×	6 6 =	9 2.30
2 6 ×	2 9 =	3 8.59	6 9 ×	6 9 =	9 6.55
2 9 ×	2 9 =	3 10.66	7 0 ×	7 0 =	9 10.79
2 9 ×	3 0 =	4 0.83	7 3 ×	7 3 =	10 3.03
3 0 ×	3 0 =	4 2.91	7 6 ×	7 6 =	10 7.28
3 0 ×	3 3 =	4 5.02	7 9 ×	7 9 =	10 11.52
3 0 ×	3 6 =	4 7.31	8 0 ×	8 0 =	11 3.76
3 0 ×	3 9 =	4 9.62	8 3 ×	8 3 =	11 8.00
3 3 ×	3 3 =	4 7.15	8 6 ×	8 6 =	12 0.24
3 3 ×	3 6 =	4 9.31	8 9 ×	8 9 =	12 4.49
3 3 ×	3 9 =	4 11.54	9 0 ×	9 0 =	12 8.73
3 3 ×	4 0 =	5 1.84	9 6 ×	9 6 =	13 5.22
3 6 ×	3 6 =	4 11.39	10 0 ×	10 0 =	14 1.70
3 6 ×	3 9 =	5 1.55	10 6 ×	10 6 =	14 10.19
3 6 ×	4 0 =	5 3.78	11 0 ×	11 0 =	15 6.67
3 9 ×	3 9 =	5 3.63	11 6 ×	11 6 =	16 3.16
3 9 ×	4 0 =	5 5.79	12 0 ×	12 0 =	16 11.64
4 0 ×	4 0 =	5 7.88	12 6 ×	12 6 =	17 8.13
4 0 ×	4 3 =	5 10.03	13 0 ×	13 0 =	18 4.61
4 0 ×	4 6 =	6 0.25	13 6 ×	13 6 =	19 1.10
4 0 ×	4 9 =	6 2.51	14 0 ×	14 0 =	19 9.58
4 0 ×	5 0 =	6 4.83			

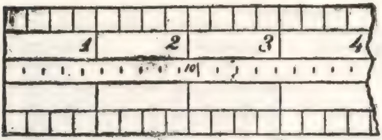


Fig. 22.

There is on the tongue of the square a scale called the "octagonal scale." This is generally on the opposite side to the scales shown on Fig. 19. Fig. 22 exhibits a portion of the tongue on which this scale is shown. It is the central division on which the number 10 is seen along with a number of divisions. It is used in this way: If you have a stick 10 inches square which you wish to dress up octagonal, make a center mark on each face, then with the compasses, take 10 of the spaces marked by the short cross-lines in the middle of the scale, and lay off this distance each side of the center lines, do the same at the other end of the stick, and strike a chalk line through these marks. Dress off the corners to the lines, and the stick will be octagonal. If the stick is not straight it must be gauged, and not marked with the chalk line. Always take a number of spaces equal to the square width of the octagon in inches. This scale can be used for large octagons by doubling or trebling the measurements.

Fig. 23.

On some squares, there are other scales, but I do not advise the use of squares that are surcharged with too many scales and figures, as they lead to confusion and loss of time.

It will now be in order to offer a few things that can be done with the steel square, in a shorter time than by applying any other methods. If we wish to get the

length and bevels for any common rafter it can be done on short notice by using the square as shown in Fig. 23. The pitch of the roof will, of course, govern the figures to be employed on the blade and tongue. For a quarter pitch, the figures must be 6 and 12. For half pitch, 12 and 12 must be used. For a steeper pitch, 12 and a larger figure must be used according to the pitch required. For the lower pitches, 8 and 12 gives a one-third pitch and 9 and 12 a still steeper pitch; and from this the workman can obtain any pitch he requires. If the span is 24 feet, the square must be applied 12 times, as 12 is half of 24. And so with any other span: The square must be applied half as many times as there are feet in the width. This is self-evident. The bevels and lengths of hip and valley rafters may be obtained in a similar manner, by first taking the length of the diagonal line between 12 and 12, on the square, which is 17 inches in round numbers. Use this figure on the blade, and the "rise" whatever that may be, on the tongue. Suppose we have a roof of one-third pitch, which has a span of 24 feet; then 8, which is one-third of 24, will be the height of the roof at the point or ridge, from the base of the roof on a line with the plates. For example, always use 8, which is one-third of 24, on tongue for altitude; 12, half the width of 24, on blade for base. This cuts common rafter. Next is the hip rafter. It must be understood that the diagonal of 12 and 12 is 17 in framing, as before stated, and the hip is the diagonal of a square added to the rise of roof; therefore we take 8 on tongue and 17 on blade; run the same number of times as common rafter. To cut jack rafters, divide the number of openings for common rafter. Suppose we have 5 jacks, with six open-

ings, our common rafter 12 feet long, each jack would be 2 feet shorter, first 10 feet, second 8 feet, third 6 feet, and so on. The top down cut the same as cut of common rafter; foot also the same. To cut miter to fit hip: Take half the width of building on tongue and length of common rafter on blade; blade gives cut. Now find the diagonal of 8 and 12, which is $14\frac{7}{16}$, take 12 on tongue, $14\frac{7}{16}$ on blade; blade gives cut. The hip rafter must be beveled to suit; height of hip on tongue, length of hip on blade; tongue gives bevel. Then we take 8 on tongue, 8¾ on blade; tongue gives the bevel. Those figures will span all cuts in putting on cornice or sheathing. To cut bed moulds for gable to fit under cornice, take half width of building on tongue, length of common rafter on blade; blade gives cut; machine mouldings will not member, but this gives a solid joint; and to member properly it is necessary to make moulding by hand, the diagonal plumb cut differences. To cut planceer to run up valley, take height of rafter on tongue, length of rafter on blade; tongue gives cut. The plumb cut takes the height of hip rafter on tongue, length of hip rafter on blade; tongue gives cut. These figures give the cuts for one-third pitch only, regardless of width of building. The construction of roofs generally will be taken up in another chapter.

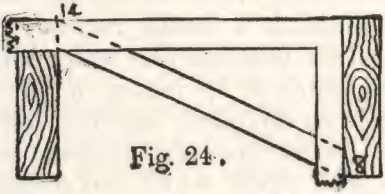


Fig. 24.

A ready way of finding the length and cuts for cross-bridging is shown at Fig. 24. If the joists are 8 inches wide and 16 inches centers, there will be 14 inches

between. Place the square on 8 and 14, and cut on 8, and you have it. The only point to observe is that the 8 is on the lower side of the piece of bridging, while the 14 is on the upper, and not both on same side of timber, as in nearly all work. Bridging for any depth of joists, to any reasonable distance of joists apart, may be obtained by this method. A quick way of finding the joists for laying out timber to be worked from the square to an octagon section is shown at Fig. 25. Lay your square diagonally across your timber and mark at 7 and 17, which gives corner of octagon. The figures 7 and 17, on either a square or two-foot pocket rule, when laid on a board or piece of timber as shown, always define the points where the octagonal angle or arris should be.

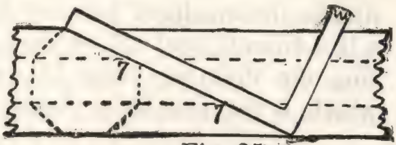


Fig. 25.

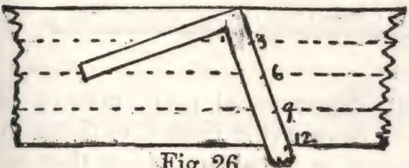


Fig. 26.

Fig. 26 shows a rapid method of dividing anything into several equal parts. If the board is 10½ inches wide, lay the square from heel to 12, and mark at 3, 6 and 9, and you have it divided into four equal parts. Any width of board or any number of parts may be worked with accuracy under the same method.

A method for obtaining the "cuts" for octagon and hexagon joints is shown at Fig. 27. Lay off a quarter circle XA, with C as a center; then along the horizontal line AB the square is laid with 12″ on the blade

at the center C, from which the quadrant was struck. If we divide this quadrant into halves, we get the point E, and a line drawn from 12″ on the blade of the square and through the point E, we cut the tongue of the square at 12″ and through to O, and the line thus drawn makes an angle of 45°, a true miter. If we divide the quadrant between E and X, and then draw a line from C, and 12″ on the blade of the square, cutting the dividing point D, we get the octagon cut, which is the line DC. Again, if we divide the space

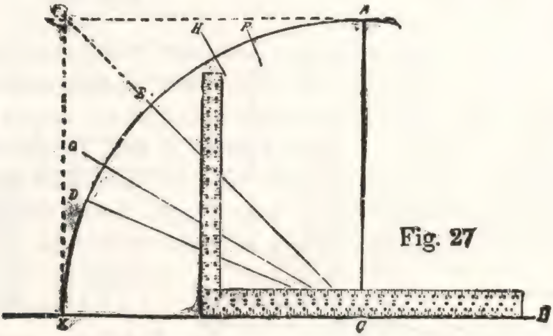


Fig. 27

between E and X into three equal parts, making GC one of these parts, and draw a line from C to G cutting the tongue of the square at 7″, we get a cut that will give us a miter for a hexagon; therefore, we see from this that if we set a steel square on any straight edge or straight line, 12″ and 12″ on blade and tongue on the line or edge, we get a true miter by marking along the edge of the blade. For an octagon miter, we set the blade on the line at 12″, and the tongue at 5″, and we get the angle on the line of the blade—nearly; and, for a hexagon cut, we place the blade at 12″ on the

line, and the tongue at 7″, and the line of the blade gives the angle of cut—nearly. The actual figure for octagon is $4\frac{31}{32}$, but 5″ is close enough; and for a hexagon cut, the exact figures are 12″ and $6\frac{15}{16}$, but 12″ and 7″ is as near as most workmen will require, unless the cut is a very long one.

The diagram shown at Fig. 28 illustrates a method of defining the pitches of roofs, and also gives the figures on the square for laying out the rafters for such pitches. By a very common usage among carpenters and builders, the pitch of a roof is described by indicating what fraction the rise is of the span. If, for example, the span is 24 feet (and here it should be remarked that the diagram shows only one-half the span), then 6 feet rise would be called quarter pitch, because 6 is one-quarter of 24. The rule, somewhat arbitrarily expressed, that is applicable in such cases in roof framing where the roof is one-quarter pitch, is as follows: Use 12 of the blade, and 6 of the tongue. For other pitches use the figures appropriate thereto in the same general manner.

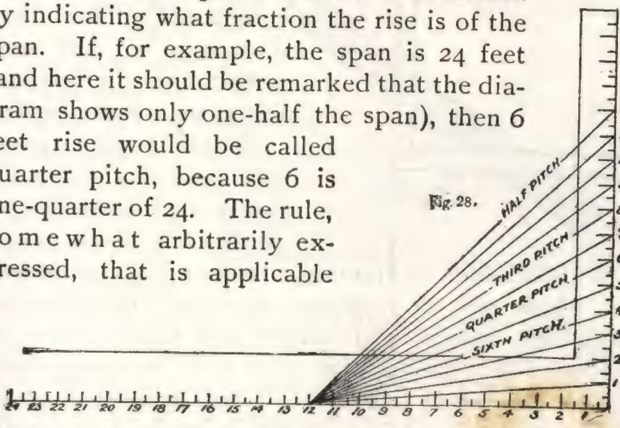


Fig. 28.

The diagram indicates the figures for sixth pitch, quarter pitch, third pitch and half pitch. The first three of these are in very common use, although the latter is somewhat exceptional.

It will take but a moment's reflection upon the part

of a practical man, with this diagram before him, to perceive that no changes are necessary in the rule where the span is more or less than 24 feet. The cuts are the same for quarter pitch irrespective of the actual dimensions of the building. The square in all such cases is used on the basis of similar triangles. The broad rule is simply this: To construct with the square such a triangle as will proportionately and correctly represent the full size, the blade becomes the base, the tongue the altitude or rise, while the hypothenuse that results represents the rafter. The necessary cuts are shown by the tongue and blade respectively.

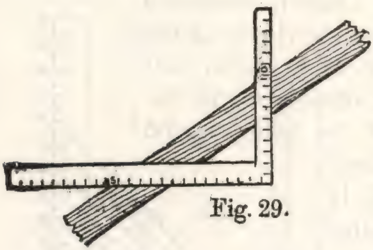


Fig. 29.

In order to give a general idea of the use of the square I herewith append a few illustrations of its application in framing a roof of, say, one-third pitch, which will be supposed to consist of common rafters, hips, valleys, jack rafters and ridges. Let it be assumed that the building to be dealt with measures 30 feet from outside to outside of wall plates; the toe of the rafters to be fair with the outside of the wall plates, the pitch being one-third (that is the roof rises from the top of the wall plate to the top of the ridge, one-third of the width of the building, or 10 feet), the half width of the building being 15 feet. Thus, the figures for working on the square are obtained; if other figures are used, they must bear the same relative proportion to each other.

To get the required lengths of the stuff, measure across the corner of the square, from the 10-inch mark

at the tongue to the 15-inch mark on the blade, Fig. 29. This gives 18 feet as the length of the common rafter. To get the bottom bevel or cut to fit on the wall plate, lay the square flat on the side of the rafter. Start, say, at the right-hand end, with the blade of the square to the right, the point or angle of the square away from you, and the rafter, with its back (or what will be the top edge of it when it is fixed) towards you. Now place the 15-inch mark of the blade and the 10-inch mark of the tongue on the corner of the rafter—that is, towards you—still keeping the square laid flat, and mark along the side of the blade. This gives the bottom cut, and will fit the wall plate. Now move the square to the other end of the rafter, place it in the same position as before to the 18-foot mark on the rafter and to the 10-inch mark on the tongue, and the 15-inch mark on the blade; then mark alongside the tongue. This gives the top cut to fit against the ridge. To get the length of the hip rafter, take 15 inches on the blade and 15 inches on the tongue of the square, and measure across the corner. This gives $21\frac{3}{16}$ inches. Now take this figure on the blade and 10 inches on the tongue, then measuring across the corner gives the length of the hip rafter.

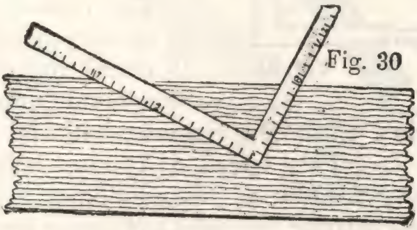


Fig. 30

Another method is to take the 17-inch mark on the blade and the 8-inch mark on the tongue and begin as with the common rafter, as at Fig. 30. Mark along

the side of the blade for the bottom cut. Move the square to the left as many times as there are feet in the half of the width of the building (in the present case, as we have seen, 15 feet is half the width), keeping the above mentioned figures 17 and 8 in line with the top edge of the hip rafter; step it along just the same as when applying a pitch board on a stair-string, and after moving it along 15 steps, mark alongside the tongue. This gives the top cut or bevel and the length. The reason 17 and 8 are taken on the square is that 12 and 8 represent the rise and run of the common rafter to 1 foot on plan, while 17 and 8 correspond with the plan of the hips.

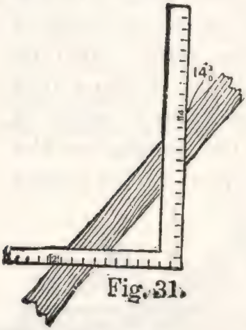


Fig. 31.

To get the length of the jack rafters, proceed in the same manner as for common or hip rafters; or alternately space the jacks and divide the length of the common rafter into the same number of spaces. This gives the length of each jack rafter.

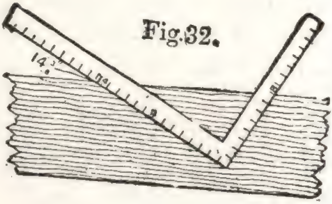


Fig. 32.

To get the bevel of the top edge of the jack rafter, Fig. 31, take the length, 14⅜ of the common rafter on the blade and the run of the common rafter on the tongue, apply the square to the jack rafter, and mark along the side of the blade; this gives the bevel or cut. The down bevel and the bevel at the bottom end are the same as for the common rafter.

To get the bevel for the side of the purlin to fit

against the hip rafter, place the square flat against the side of the purlin, with 8 inches on the tongue and 14⅜ inches on the blade, Fig. 32. Mark alongside of the tongue. This gives the side cut or bevel. The 14⅜ inches is the length of the common rafter to the 1-foot run, and the 8 inches represent the rise.

For the edge bevel of purlin, lay the square flat against the edge of purlin with 12 inches on the tongue and 14⅓ inches on the blade, as at Fig. 33, and mark along the side of the tongue. This gives the bevel or cut for the edge of the purlin.

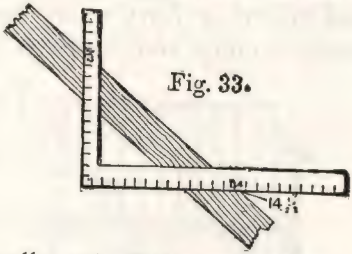


Fig. 33.

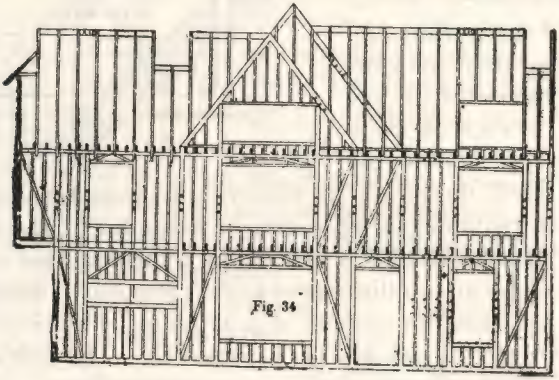
The rafter patterns must be cut half the thickness of ridge shorter; and half the thickness of the hip rafter allowed off the jack rafters.

These examples of what may be achieved by the aid of the square are only a few of the hundreds that can be solved by an intelligent use of that wonderful instrument, but it is impossible in a work of this kind to illustrate more than are here presented. The subject will be dealt with at length in a separate volume.

CHAPTER II

GENERAL FRAMING AND ROOFING

Heavy framing is now almost a dead science in this country unless it be in the far west or south, as steel and iron have displaced the heavy timber structures that thirty or forty years ago were so plentiful in roofs, bridges and trestle-work. As it will not be



necessary to go deeply into heavy-timber framing, therefore I will confine myself more particularly to the framing of ballon buildings generally.

A ballon frame consists chiefly of a frame-work of scantling. The scantling may be 2 x 4 inches, or any other size that may be determined. The scantlings are spiked to the sills, or are nailed to the sides of the joist which rests on the sills, or, as is sometimes the case, a rough floor may be nailed on the joists,

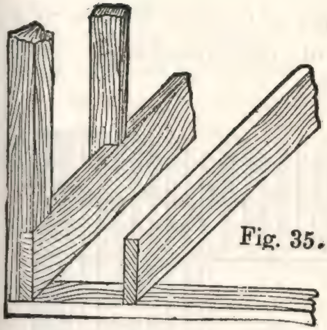


Fig. 35.

and on this, ribbon pieces of 2 x 4-inch stuff are spiked around to the outer edge of the foundation, and onto these ribbon pieces the scantling is placed and "toe-nailed" to them. The doors and windows are spaced off as shown in Fig. 34, which represents a ballon frame and roof in skeleton condition. These frames are generally boarded on both sides, always on the outside. Sometimes the boarding on the outside is nailed on diagonally, but more frequently horizontally, which, in my opinion, is the better way, providing always the boarding is dry and the joints laid close.

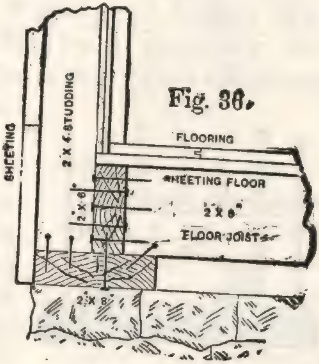


Fig. 36.

The joists are laid on "rolling," that is, there are no gains or tenons employed, unless in trimmers or similar work. The joists are simply "toe-nailed" onto sill plates, or ribbon pieces, as shown in the illustration. Sometimes the joists are made to rest on the sills, as shown in Fig. 35, the sill being no more than a 2 x 4-inch scantling laid in mortar on the foundation, the outside joists forming a sill for the side studs. A better plan is

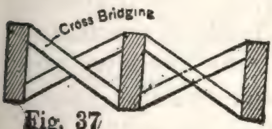


Fig. 37

shown in Fig. 36, which gives a method known as a "box-sill." The manner of construction is very simple.

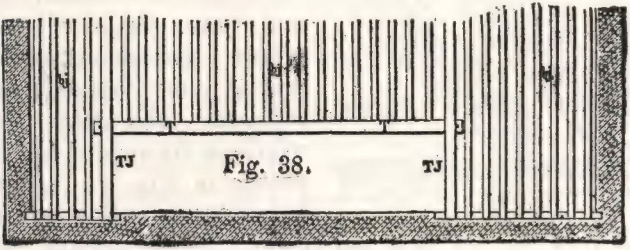


Fig. 38.

All joists in a building of this kind must be bridged similar to the manner shown in Fig. 37, about every eight feet of their length; in spans less than sixteen feet, and more than eight feet, a row of bridging should always be put in midway in the span. Bridging should not be less than 1 to 1½ inches in section.

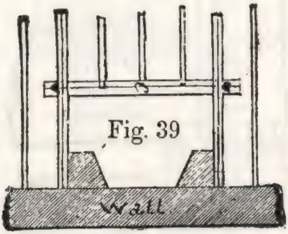


Fig. 39

In trimming around a chimney or a stair well-hole, several methods are employed. Sometimes the headers and trimmers are made from material twice as thick and the same depth as the ordinary joists, and the intermediate joists are tenoned into the header, as shown in Fig. 38. Here we have T, T, for header, and T, J, T, J, for trimmers, and *b*, *j*, for the ordinary joists. In the western, and also some of the central States, the trimmers and headers are made up of two thicknesses, the header being mortised to secure the ends of the joists. The

two thicknesses are well nailed together. This method is exhibited at Fig. 39., which also shows one way to trim around a hearth; C shows the header with trimmer joists with tusk tenons, keyed solid in place.

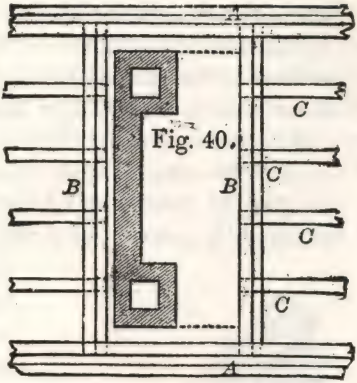


Fig. 40.

Frequently it happens that a chimney rises in a building from its own foundation, disconnected from the walls, in which case the chimney shaft will require to be trimmed all around, as shown in

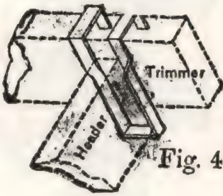


Fig. 41.

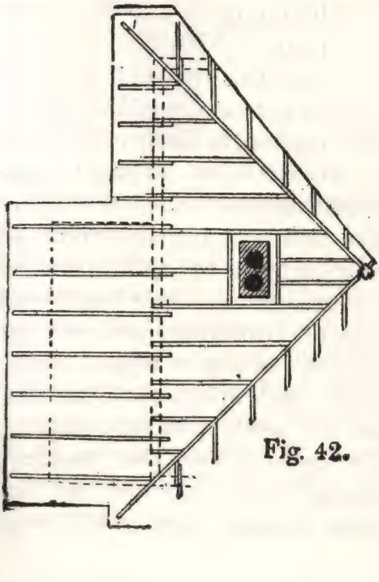


Fig. 42.

Fig. 40. In cases of this kind the trimmers A, A, should be made of stuff very much thicker than the joists, as they have to bear a double burden; B, B shows the heading, and C, C, C, C the tail joists. B, B, should have a thickness double that of C, C, etc., and A, A should at least be

three times as stout as C, C. This will to some extent equalize the strength of the whole floor, which is a matter to be considered in laying down floor timbers, for a floor is no stronger than its weakest part.

There are a number of devices for trimming around stairs, fire-places and chimney-stacks by which the cutting or mortising of the timbers is avoided. One method is to cut the timbers the exact length, square in the ends, and then insert iron dowels—two or more—in the ends of the joists, and then bore holes in the trimmers and headers to suit, and drive the whole solid together. The dowels are made from ¾-inch or 1-inch round iron. Another and a better device is the "bridle iron," which may be hooked over the trimmer or header, as the case may be, the stirrup carrying the abutting timber, as shown in Fig. 41.

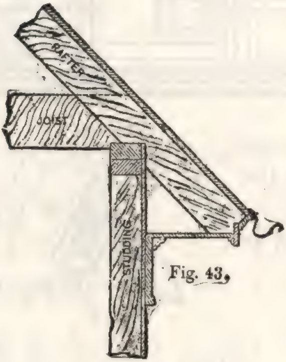


Fig. 43.

These "bridle irons" are made of wrought iron—2 x 2½ inches, or larger dimensions if the work requires such; for ordinary jobs, however, the size given will be found plenty heavy for carrying the tail joists, and a little heavier may be employed to carry the header. This style of connecting the trimmings does not hold the frame-work together, and in places where there is any tendency to thrust the work apart, some provision must be made to prevent the work from spreading.

In trimming for a chimney in a roof, the "headers," "stretchers" or "trimmers," and "tail rafters," may be simply nailed in place, as there is no great weight

beyond snow and wind pressure to carry, therefore the same precautions for strength are not necessary. The sketch shown at Fig. 42 explains how the chimney openings in the roof may be trimmed, the parts being only spiked together. A shows a hip rafter against which the cripples on both sides are spiked. The chimney-stack is shown in the center of the roof—isolated—trimmed on the four sides. The sketch is

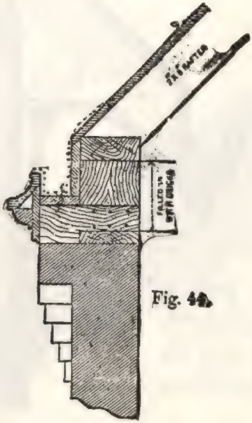


Fig. 44.

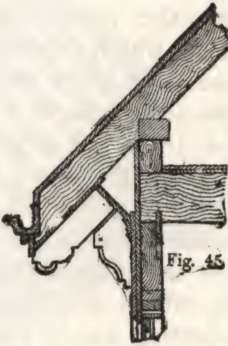


Fig. 45

self-explanatory in a measure, and should be easily understood.

An example or two showing how the rafters may be connected with the plates at the eaves and finished for cornice and gutters, may not be out of place. A simple method is shown at Fig. 43, where the cornice is complete and consists of a few members only. The gutter is attached to the crown moulding, as shown.

Another method is shown at Fig. 44, this one being intended for a brick wall having sailing courses over cornice. The gutter is built in of wood, and is

lined throughout with galvanized iron This makes a substantial job and may be used to good purpose on brick or stone warehouses, factories or similar buildings.

Another style of rafter finish is shown at Fig. 45, which also shows scheme of cornice. A similar finish is shown at Fig. 46, the cornice being a little different. In both these examples, the gutters are of wood, which should be lined with sheet metal of some sort in order to prevent their too rapid decay. At Fig. 47 a rafter finish is shown which is intended for a veranda or porch. Here the construction is very simple. The rafters are dressed and cut on projecting end to represent brackets and form a finish

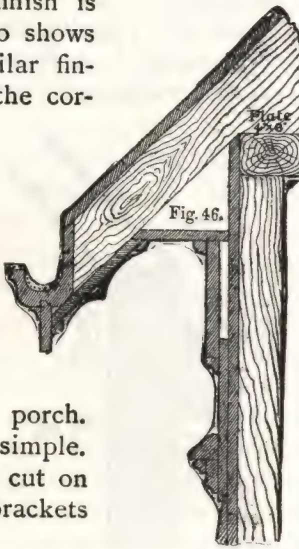


Fig. 46.

From these examples the workman will get sufficient ideas for working his rafters to suit almost any condition. Though there are many hundreds of styles which might be presented, the foregoing are ample for our purpose.

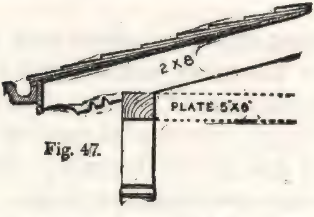


Fig. 47.

It will now be in order to take up the construction of roofs, and describe the methods by which such construction is obtained.

The method of obtaining the lengths and bevels of

rafters for ordinary roofs, such as that shown in Fig. 48, has already been given in the chapter on the steel square. Something has also been said regarding hip and valley roofs; but not enough, I think, to satisfy the full requirements of the workman, so I will endeavor to give a clearer idea of the construction of these roofs by employing the graphic system, instead of depending altogether on the steel square, though I

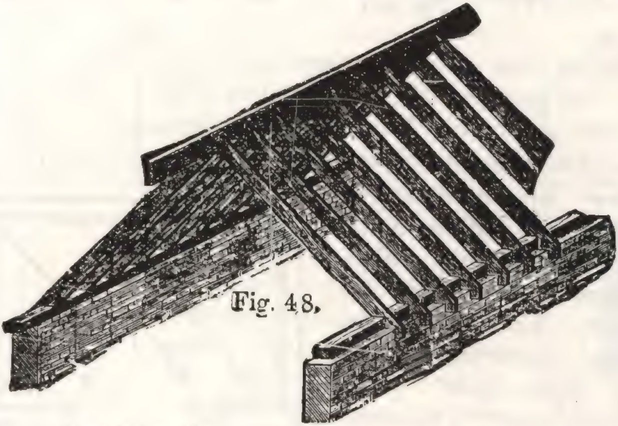


Fig. 48.

earnestly advise the workman to "stick to the square." It never makes a mistake, though the owner may in its application.

A "hip roof," pure and simple, has no gables, and is often called a "cottage roof," because of its being best adapted for cottages having only one, or one and a half, stories. The chief difficulty in its construction is getting the lengths and bevels of the hip or angle rafter and the jack or cripple rafter. To the expert workman, this is an easy matter, as he can readily obtain both lengths and bevels by aid of the square, or by lines such as I am about to produce.

The illustration shown at Fig. 49 shows the simplest form of a hip roof. Here the four hips or diagonal rafters meet in the center of the plan. Another style of hip roof, having a gable and a ridge in the center of the building, is shown at Fig. 50. This is quite a common style of roof, and under almost every condition it looks well and has a good effect. The plan shows lines of hips, valleys and ridges.

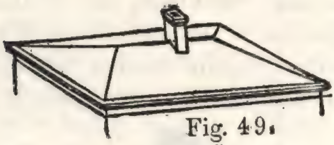


Fig. 49.

The simplest form of roof is that known as the "lean-to" roof. This is formed by causing one side wall to be raised higher than the opposite side wall, so that when rafters or joists are laid from the high to the low wall a sloping roof is the result. This style of a roof is sometimes called a "shed roof" or a "pent roof." The shape is shown at Fig. 51, the upper sketch showing an end view and the lower one a plan of the roof. The method of framing this roof, or adjusting the timbers for it, is quite obvious and needs no explanation. This style of roof is in general use where an annex or shed is built up against a superior building, hence its name of "lean-to," as it usually "leans" against the main building, the wall of which is utilized for the

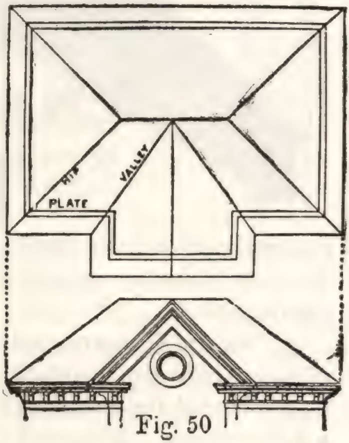


Fig. 50

high part of the shed or annex, thus saving the cost of the most important wall of the structure.

Next to the "lean-to" or "shed roof" in simplicity comes the "saddle" or "double roof." This roof is shown at Fig. 52 by the end view on the top of the figure, and the plan at the bottom. It will be seen that this roof has a double slope, the planes forming the slopes are equally inclined to the horizon; the meeting of their highest sides makes an arris which is called the ridge of the roof; and the triangular spaces at the end of the walls are called gables.

It is but a few years ago when the mansard roof was very popular, and many of them can be found in the older parts of the country, having been erected between the early fifties and the eighties, but, for many reasons, they are now less used. Fig. 53 shows a roof of this kind. It is penetrated generally by dormers, as shown in the sketch, and the top is covered either by a "deck roof" or a very flat hip roof, as shown. Sometimes the sloping sides of these roofs are curved, which give them a graceful appearance, but adds materially to their cost.

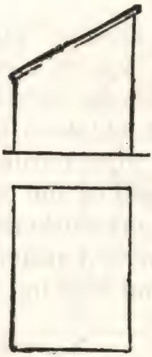


Fig. 51.

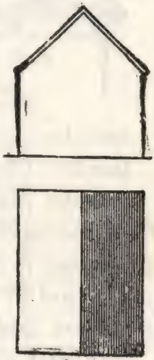


Fig. 52.

Another style of roof is shown at Fig. 54. This is a gambrel roof, and was very much in evidence in pre-revolutionary times, particularly among our Knickerbocker ancestors. In conjunction with appropriate dormers, this style of roof figures prominently in what is known as early "colonial style." It has some

advantages over the mansard. Besides these there are many other kinds of roofs, but it is not my purpose to enter largely into the matter of styles of roofs, but simply to arm the workman with such rules and practical equipment that he will be able to tackle with success almost any kind of a roof that he may be called upon to construct.

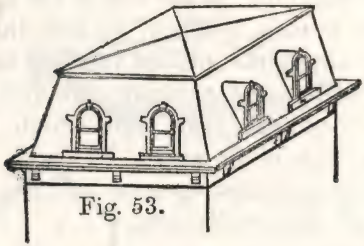


Fig. 53.

When dealing with the steel square I explained how the lengths and bevels for common rafters could be obtained by the use of the steel square alone; also hips, purlins, valleys and jack rafters might be obtained by the use of the square, but, in order to fully equip the workman, I deem it necessary to present for his benefit a graphic method of obtaining the lengths, cuts and backing of rafters and purlins required for a hip roof.

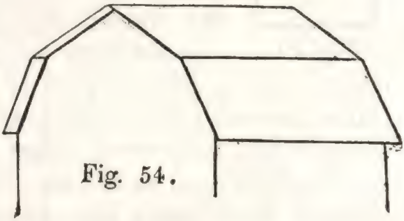


Fig. 54.

At Fig. 55, I show the plans of a simple hip roof having a ridge. The hips on the plan form an angle of 45°, or a miter, as it were. The plan being rectangular leaves the ridge the length of the difference between the length and the width of the building. Make *cd* on the ridge-line as shown, half the width of *ab*, and the angle *bda* will be a right angle. Then if we extend *bd* to *e*, making *de* the rise of the roof, *ae* will be the length of the hip rafter, and the

angle at *x* will be the plumb cut at point of hip and the angle at *a* will be the cut at the foot of the rafter. The angle at *v* shows the backing of the hip. This bevel is obtained as follows: Make *ag* and *ah* equal distances—any distance will serve—then draw a line *hg* across the angle of the building, then with a center on *ad* at *p*, touching the line *ae* at *s*, describe a circle as shown by the dotted line, then draw the lines *kh* and

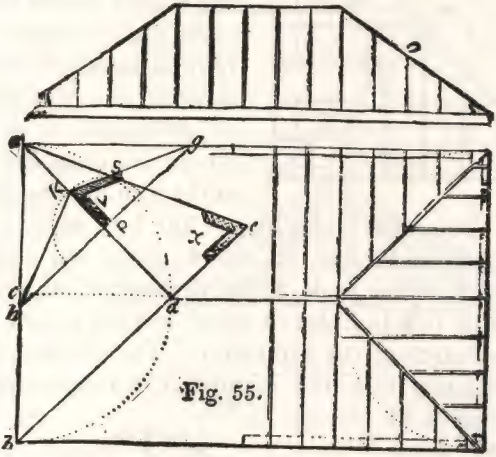


Fig. 55.

kg, and that angle, as shown by the bevel *v*, will be the backing or bevel for the top of the hip, beveling each way from a center line of the hip. This rule for backing a hip holds good in all kinds of hips, also for guttering a valley rafter, if the bevel is reversed. A hip roof where all the hips abut each other in the center is shown in Fig. 56. This style of roof is generally called a "pyramidal roof" because it has the appearance of a low flattened pyramid. The same rules governing Fig. 55 apply to this example. The bevels C and B show the backing of the hip, B showing the

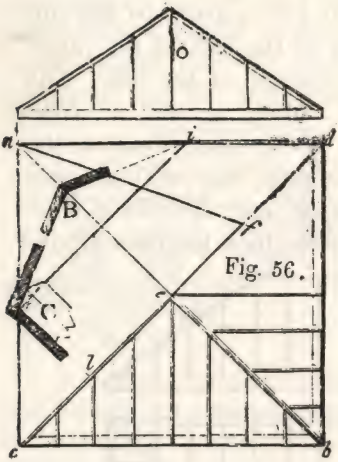


Fig. 56.

top from the center line *ae*; and C showing the bevel as placed against the side of the hip, which is always the better way to work the hip. A portion of the hip backed is shown at C. The rise of the roof is shown at O.

At Fig. 57 a plan of a roof is shown where the seats of the hips are not on an angle of 45° and where the ends and sides of the roof are of different pitches Take the base line of the hip, *ae* or *eg*, and make *ef* perpendicular to *ae*, from *e*, and equal to the rise at *f*; make *fa* or *fg* for the length of the hip, by drawing the line *lm* at right angles to *ae*. This gives the length of the hip rafter. The backing of the hip is obtained in a like manner to former examples, only, in cases of this kind, there are two bevels for the backing, one side of the hip being more acute than the other as shown at D and E. If the hips are to be mitered, as is sometimes the case in roofs of this kind, then

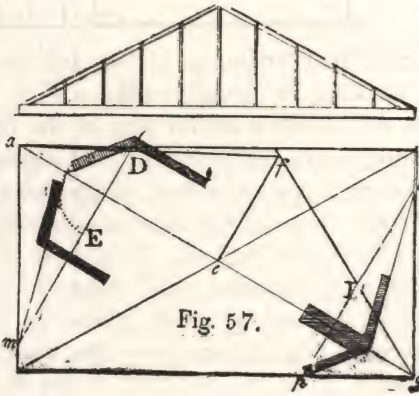


Fig. 57.

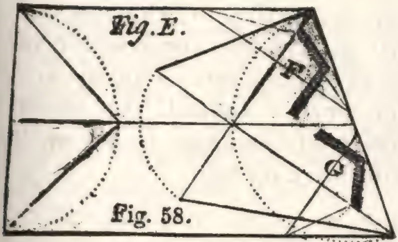


Fig. 58.

the back of the hip will assume the shape as shown by the two bevels at F. A hip roof having an irregular plan is shown at Fig. 58. This requires no explanation, as the hips and bevels are obtained in the same manner as in previous examples. The backing of the hips is shown at FG.

An octagon roof is shown at Fig. 59, with all the lines necessary for getting the lengths, bevels, and backing for the hips. The line *ax* shows the seat of the hip, *xe* the rise of roof, and *ae* the length of hip and plumb cut, and the bevel at E shows the backing of the hips.

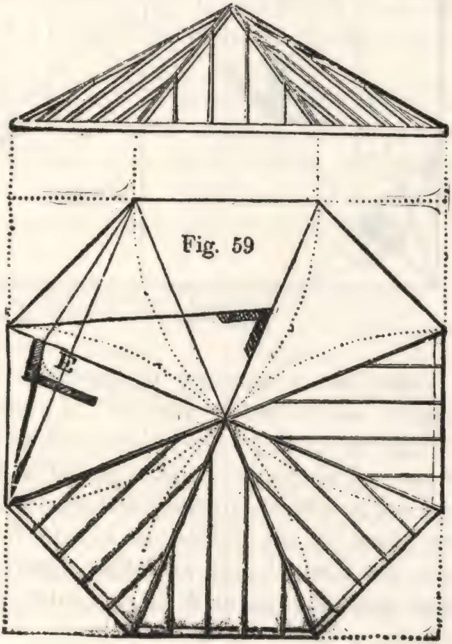


Fig. 59

These examples will be quite sufficient to enable the workman to understand the general theory of laying out hip roofs. I

may also state that to save a repetition of drawing and explaining the rules that govern the construction of hip roofs, such as I have presented serve equally well for skylights or similar work. Indeed, the clever workman will find hundreds of instances in his work where the rules given will prove useful.

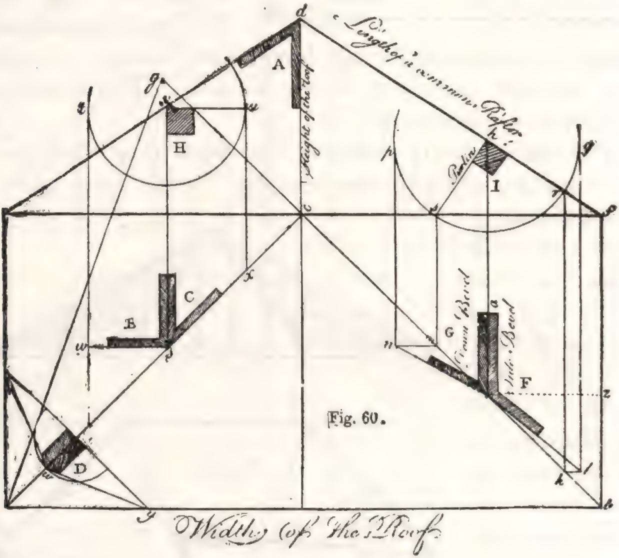


Fig. 60.

There are a number of methods for getting the lengths and bevels for purlins. I give one here which I think is equal to any other, and perhaps as simple. Suppose Fig. 60 shows one end of a hip roof, also the rise and length of common rafters. Let the purlin be in any place on the rafter, as I, and in its most common position, that is, standing square with the rafter: then with the point *b* as a center with any radius, describe a circle. Draw two lines, *ql* and *pn*, to touch

the circle *p* and *q* parallel to *fb* and at the points *s* and *r*, where the two sides of the purlin intersect, draw two parallel lines to the former, to cut the diagonal in *m* and *k*; then G is the down bevel and F the side bevel of the purlin; these two bevels, when applied to the end of the purlin, and when cut by them, will exactly fit the side of the hip rafters.

To find the cuts of a purlin where two sides are parallel to horizon: The square at B and the bevel at C will show how to draw the end of the purlin in this easy case. The following is universal in all positions of the purlin: Let *ab* be the width of a square roof, make *bf* or *ae* one-half of the width, and make *cd* perpendicular in the middle of *ef*, the height of the roof or rise, which in this case is one-third; then draw *de* and *df*, which are each the length of the common rafter.

To find the bevel of a jack rafter against the hip, proceed as follows: Turn the stock of the side bevel at F from *a* around to the line *iz*, which will give the side bevel of the jack rafter The bevel at A, which is the top of the common rafter, is the down bevel of the jack rafter.

At D the method of getting the backing of a hip rafter is shown the same as explained in other figures.

There are other methods of obtaining bevels for purlins, but the one offered here will suffice for all practical purposes.

I gave a method of finding the back cuts for jack rafters by the steel square, in a previous chapter. I give another rule herewith for the steel square: Take the length of the common rafter on the blade and the run of the same rafter on the tongue, and the blade of the square will give the bevel for the cut on the back

of the jack rafter. For example, suppose the rise to be 6 feet and the run 8 feet, the length of the common rafter will be 10 feet. Then take 10 feet on the blade of the square, and 8 feet on the tongue, and the blade will give the back bevel for the cut of the jack rafters.

To obtain the length of jack rafters is a very simple process, and may be obtained easily by a diagram, as shown in Fig. 61, which is a very common method: First lay off half the width of the building to scale, as from A to B, the length of the common rafter B to C, and the length of the hip rafter from A to C. Space off the widths from jack rafter to jack rafter as shown by the lines 1, 2, 3, and measure them accurately. Then the lines 1, 2 and 3 will be the exact lengths of the jack rafters in those divisions. Any number of jack rafters may be laid off this way, and the result will be the length of each rafter, no matter what may be the pitch of the roof or the distance the rafters are apart.

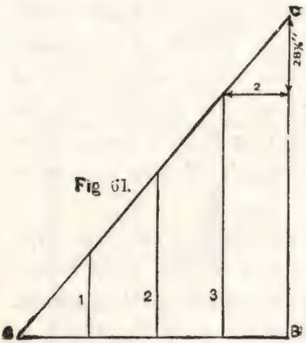


Fig 61.

A table for determining the length of jack rafters is given below, which shows the lengths required for different spacing in three pitches:

One-quarter pitch roof:

They cut 13.5 inches shorter each time when spaced 12 inches.

They cut 18 inches shorter each time when spaced 16 inches.

They cut 27 inches shorter each time when spaced 24 inches.

One-third pitch roof:

They cut 14.4 inches shorter each time when spaced 12 inches.

They cut 19.2 inches shorter each time when spaced 16 inches.

They cut 28.8 inches shorter each time when spaced 24 inches.

One-half pitch roof:

They cut 17 inches shorter each time when spaced 12 inches.

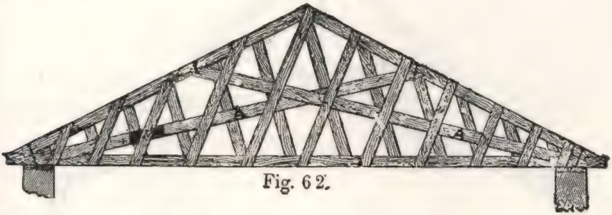


Fig. 62.

They cut 22.6 inches shorter each time when spaced 16 inches.

They cut 34 inches shorter each time when spaced 24 inches.

It is not my intention to enter deeply into a discussion of the proper methods of constructing roofs of all shapes, though a few hints and diagrams of octagonal, domical and other roofs and spires will doubtless be of service to the general workman. One of the most useful methods of trussing a roof is that known as a lattice "built-up" truss roof, similar to that shown at Fig. 62. The rafters, tie beams and the two main braces A, A, must be of one thickness—say, 2 x 4 or 2 x 6 inches, according to the length of the span—while the minor braces are made of 1-inch stuff and

about 10 or 12 inches wide. These minor braces are well nailed to the tie beams, main braces and rafters. The main braces must be halved over each other at their juncture, and bolted. Sometimes the main braces are left only half the thickness of the rafters, then no halving will be necessary, but this method has the disadvantage of having the minor braces nailed to one side only. To obviate this, blocks may be nailed to the inside of the main braces to make up the thickness

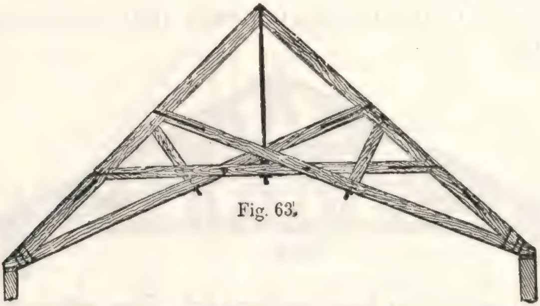


Fig. 63.

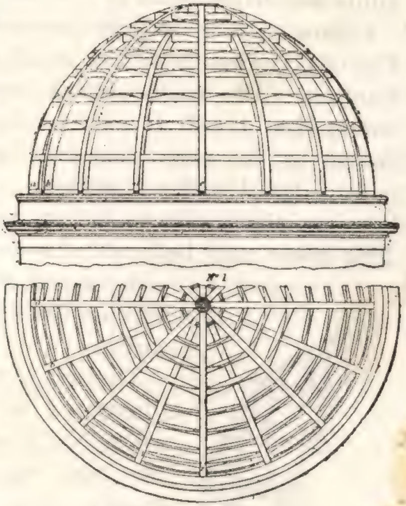
required, as shown, and the minor braces can be nailed or bolted to the main brace.

The rafters and tie beams are held together at the foot of the rafter by an iron bolt, the rafter having a crow-foot joint at the bottom, which is let into the tie beam. The main braces also are framed into the rafter with a square toe-joint and held in place with an iron bolt, and the foot of the brace is crow-footed into the tie beam over the wall.

This truss is easily made, may be put together on the ground, and, as it is light, may be hoisted in place with blocks and tackle, with but little trouble. This truss can be made sufficiently strong to span a roof from 40 to 75 feet. Where the span inclines to the

greater length, the tie beams and rafters may be made of built-up timbers, but in such a case the tie beams should not be less than 6 x 10 inches, nor the rafters less than 6 x 6 inches.

Another style of roof altogether is shown at Fig. 63. This is a self-supporting roof, but is somewhat expensive if intended for a building having a span of 30 feet or less. It is fairly well adapted for halls or for country churches, where a high ceiling is required and the span anywhere from 30 to 50 feet over all. It would not be safe to risk a roof of this kind on a building having a span more than 50 feet. The main features of this roof are: (1) having



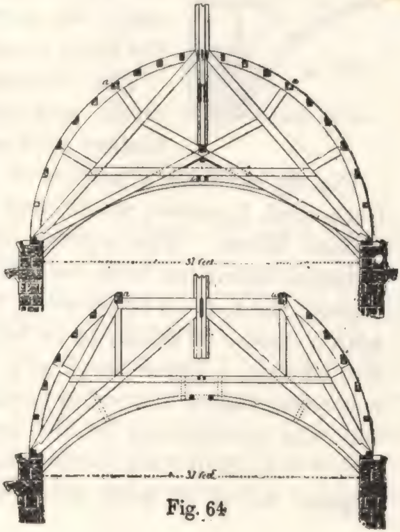


Fig. 64

collar beams, (2) truss bolts, and (3) iron straps at the joints and triple bolts at the feet.

I show a dome and the manner of its construction at Fig. 64. This is a fine example of French timber framing. The main carlins are shown at *a*, *b*, *c*, *d* and *e*, Nos. 1 and 2, and the horizontal ribs are also shown in the same numbers, with the curve of the outer edge described on them. These ribs are cut in between the carlins or rafters and beveled off to suit. This dome may be boarded over either horizontally or with boards made into "gores" and laid on in line with the rafters or carlins.

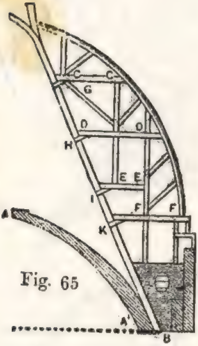


Fig. 65

The manner of framing is well illustrated in Nos. 3 and 4 in two ways, No. 3 being intended to form the two principal trusses which stretch over the whole diameter, while No. 4 may be built in between the main trusses.

The illustrations are simple and clear, and quite sufficient without further explanation.

Fig. 65 exhibits a portion of the dome of St. Paul's Cathedral, London, which was designed by Sir Christopher Wren The system of the framing of the external dome of this roof is given. The internal cupola, AA1, is of brick-work, two bricks in thickness, with a course of bricks 18 inches in length at every five feet of rise. These serve as a firm bond. This dome was turned upon a wooden center, whose only support was the projections at the springing of the dome, which is said to have been unique. Outside the brick cupola, which is only alluded to in order that the

description may be the more intelligible, rises a brickwork cone B. A portion of this can be seen, by a spectator on the floor of the cathedral, through the central opening at A. The timbers which carry the external dome rest upon this conical brickwork. The horizontal hammer beams, C, D, E. F, are curiously tied to the corbels, G, H, I, K, by iron cramps, well bedded with lead into the corbels and bolted to the hammer beams. The stairs, or ladders, by which the ascent to the Golden Gallery or the summit

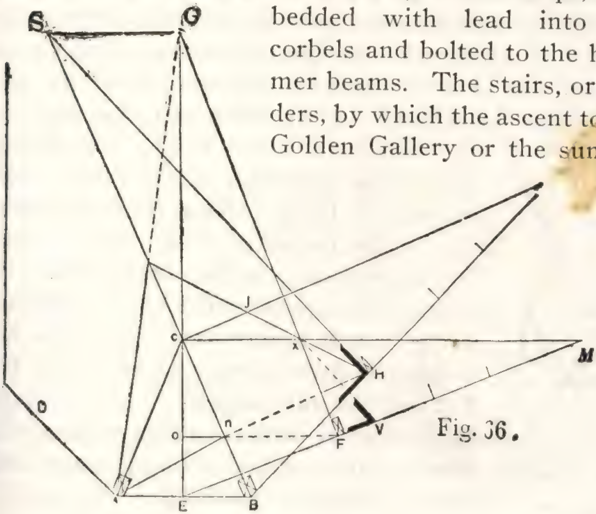


Fig. 36.

of the dome is made, pass among the roof trusses. The dome has a planking from the base upwards, and hence the principals are secured horizontally at a little distance from each other. The contour of this roof is that of a pointed dome or arch, the principals being segments of circles; but the central opening for the lantern, of course, hinders these arches from meeting at a point. The scantling of the curved principals is 10 x 11½ inches at the base, decreasing to 6 x 6 inches

at the top. A lantern of Portland stone crowns the summit of the dome. The method of framing will be clearly seen in the diagram. It is in every respect an excellent specimen of roof construction, and is worthy of the genius and mathematical skill of a great workman.

With the rules offered herewith for the construction of an octagonal spire, I close the subject of roofs: To obtain bevels and lengths of braces for an octagonal spire, or for a spire of any number of sides, let AB, Fig. 66, be one of the sides. Let AC and BC be the seat line of hip. Let AN be the seat of brace. Now, to find the position of the tie beam on the hips so as to be square with the boarding, draw a line through C, square with AB, indefinitely. From C, and square with EC, draw CM, making it equal to the height. Join EM. Let OF be the height of the tie beam. At F draw square with EM a line, which produce until it cuts EC prolonged at G. Draw CL square with BC. Make CL in length equal to EM. Join BL, and make NH equal to OF. From G draw the line GS parallel with AB, cutting BC prolonged, at the point S; then the angle at H is the bevel on the hip for the tie beam. For a bevel to miter the tie beam, make FV equal ON. Join VX; then the bevel at V is the bevel on the face. For the down bevel see V, in Fig. 67. To find the length of brace, make AB, Fig. 67, equal to AB, Fig. 66. Make AL and BL equal to BL, Fig. 66. Make BP equal to BH. Join AP and BC, which will be the length of the brace. The bevels numbered 1, 3, 5 and 7 are all to be

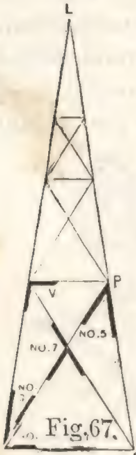


Fig. 67.

used, as shown on the edge of the brace. No. 1 is to be used at the top above No. 5. For the bevel on the face to miter on the hip, draw AG, Fig. 66, cutting BS at J. Join JH. Next, in Fig. 68, make AP equal AP, Fig. 67, and make AJ equal to AJ, Fig. 66. Make PJ equal to JH, Fig. 66, and make PI equal to HI. Join AI; then the bevel marked No. 5 will be correct for the beam next to the hip, and the bevel marked No. 6 will be correct for the top. Bevel No. 2 in this figure will be correct for the beam next to the plate. The edge of the brace is to correspond with the boarding.

Fig. 68.

A few examples of scarfing timber are presented at Figs. 69, 70, 71 and 72. The example shown at Fig. 69 exhibits a method by which the two ends of the timber are joined together with a step-splice and spur or tenon on end, it being drawn tight together by the keys, as shown in the shaded part. Fig. 70 is a similar joint though simpler, and therefore a better one; A, A are generally joggles of hardwood, and not wedged keys, but the latter are preferable, as they allow of tightening up. The shearing used along BF should be pine, and be not less than six and a half times BC; and BC should be equal to at least twice the depth of the key. The shear in the keys being at right angles to the grain of the wood, a greater stress per square inch of shearing area can be put upon them than along BF, but their shearing area should be equal in strength to the other parts of the joint; oak is the best wood for them, as its shearing is from four to five times that of pine.

Scarfed joints with bolts and indents, such as that shown at Fig. 71, are about the strongest of the kind. From this it will be seen that the strongest and most economical method in every way, in lengthening ties, is by adoption of the common scarf joint, as shown at Fig. 71, and finishing the scarf as there represented.

The carpenter meets with many conditions when timbers of various kinds have to be lengthened out

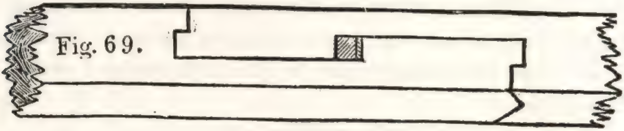


Fig. 69.

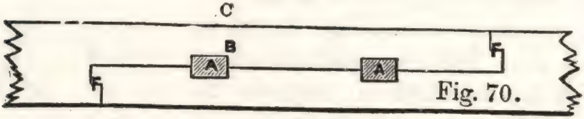


Fig. 70.

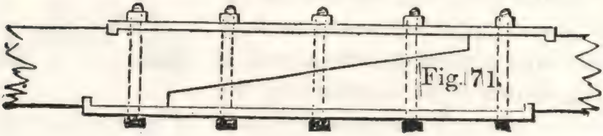


Fig. 71.

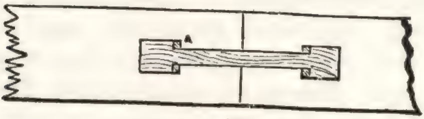


Fig. 72.

and spliced, as in the case of wall plates, etc., where there is not much tensile stress. In such cases the timbers may simply be halved together and secured with nails, spikes, bolts, screws or pins, or they may

be halved or beveled as shown in Fig. 72, which, when boarded above, as in the case of wall plates built in the wall, or as stringers on which partitions are set, or joint beams on which the lower edges of the joists rest, will hold good together.

Treadgold gives the following rules, based upon the relative resistance to tension, crushing and shearing of different woods, for the proportion which the length or overlap of a scarf should bear to the depth of the tie:

	Without bolts	With bolts	With bolts and indents
Oak, ash, elm, etc. . . .	6	3	2
Pine and similar woods .	12	6	4

There are many other kinds of scarfs that will occur to the workman, but it is thought the foregoing may be found useful on special occasions.

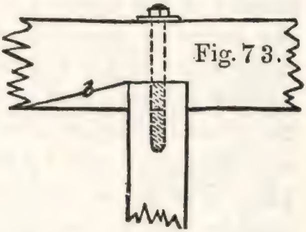
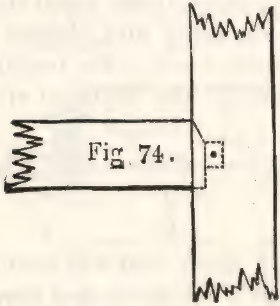


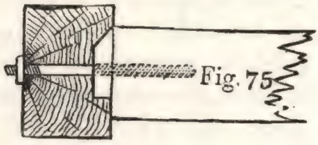
Fig. 73.

A few examples of odd joints in timber work will not be out of place. It sometimes happens that cross-beams are required to be fitted in between girders in position, as in renewing a defective one, and when this has to be done, and a mortise and tenon joint is used, a chase has to be cut leading into the mortise, as shown in the horizontal section, Fig 73. By inserting the tenon at the other end of the beams into a mortise cut so as to allow of fitting it in at an angle, the tenon can be slid along the chase *b* into its proper position. It is better in this case to dispense with the long tenon, and, if necessary, to substitute a bolt, as shown in the sketch. A mortise of this kind is called a *chase mortise*, but an

iron shoe made fast to the girder forms a better means of carrying the end of a cross-beam. The beams can be secured to the shoe with bolts or other fastenings.

To support the end of a horizontal beam or girt on the side of a post, the joint shown in Fig. 74 may be used where the mortise for the long tenon is placed, to weaken the post as little as possible, and the tenon made about one-third the thickness of the beam on which it is cut. The amount of bearing the beam has on the post must greatly depend on the work it has to do. A hardwood pin can be passed through the cheeks of the mortise and the tenon as shown to keep the latter in position, the holes being *draw-bored* in order to bring the shoulders of the tenon tight home against the post, but care must be taken not to overdo the draw-boring or the wood at the end of the tenon will be forced out by the pin. The usual rule for draw-boring is to allow a quarter of an inch *draw* in soft woods and one-eighth of an inch for hard woods. These allowances may seem rather large, but it must be remembered that both holes in tenon and mortise will give a little, so also will the draw pin itself unless it is of iron, an uncommon circumstance.





Instead of a mortise and tenon, an iron strap or a screw bolt or nut may be used, similiar to that shown in Fig. 75.

The end of the beam may also be supported on a block which should be of hardwood, spiked or bolted on to the side of the post, as at A and B, Fig. 76. The end of the beam may either be tenoned into the post as shown, or it may have a shoulder, with the end of the beam beveled, as shown at A.

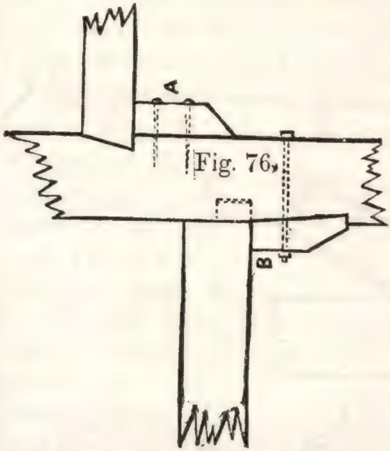


Fig. 76.

Heavy roof timbers are rapidly giving place to steel, but there yet remain many cases where timbers will remain employed and the old method of framing continued. The use of iron straps and bolts in fastening timbers together or for trussing purposes will never perhaps become obsolete, therefore a knowledge of the proper use of these will always remain valuable.

Heel straps are used to secure the joints between inclined struts and horizontal beams, such as the joints between rafters and beams. They may be placed either so as merely to hold the beams close together at the joints, as in Fig. 77, or so as to directly resist the thrust of the inclined strut and prevent it from shearing off the portion of the horizontal beam against which it presses. Straps

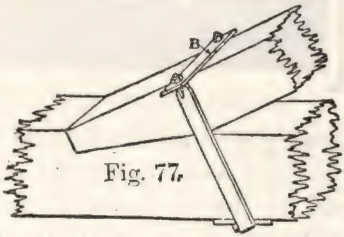


Fig. 77.

of the former kind are sometimes called *kicking-straps*. The example shown at Fig. 77 is a good form of strap for holding a principal rafter down at the foot of the tie beam. The screws and nuts are prevented from sinking into the wood by the bearing plate B, which acts as a washer on which the nuts ride when tightening is done. A check plate is also provided underneath to prevent the strap cutting into the tie beam.

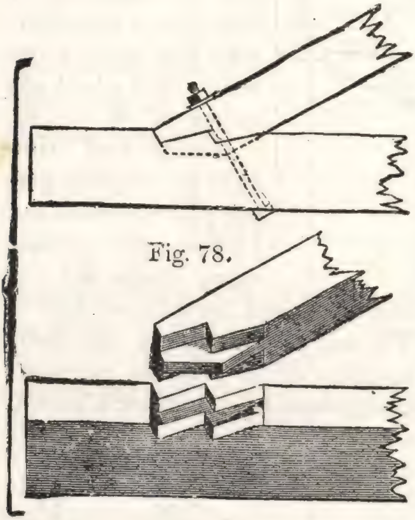


Fig. 78.

At Fig. 78 I show a form of joint often used, but it represents a difficulty in getting the two parallel abutments to take their fair share of the work, both from want of accuracy in workmanship as well as from the disturbing influence of shrinkage. In making a joint of this sort, care must be taken that sufficient wood is left between the abutments and the end of the tie beam to prevent shearing. A little judgment in using straps will often save both time and money and yet be sufficient for all purposes.

I show a few examples of strengthening and trussing joints, girders, and timbers at Fig. 79. The diagrams need no explanation, as they are self-evident.

It would expand this book far beyond the dimensions

awarded me, to even touch on all matters pertaining to carpentry, including bridges, trestles, trussed girders and trusses generally, so I must content myself

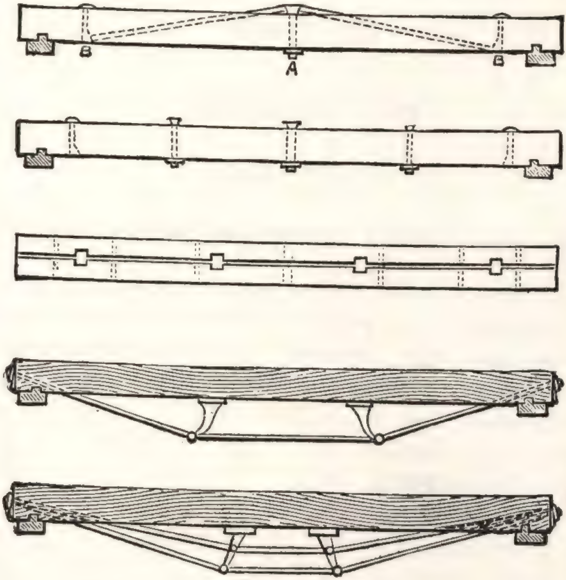


Fig. 79.

with what has already been given on the subject of carpentry, although, as the reader is aware, the subject is only surfaced.

PART III

JOINER'S WORK

CHAPTER I

KERFING, RAKING MOULDINGS, HOPPERS AND SPLAYS

This department could be extended indefinitely, as the problems in joinery are much more numerous than in carpentry, but as the limits of this book will not permit me to cover the whole range of the art, even if I were competent, I must be contented with dealing with those problems the workman will most likely be confronted with in his daily occupation.

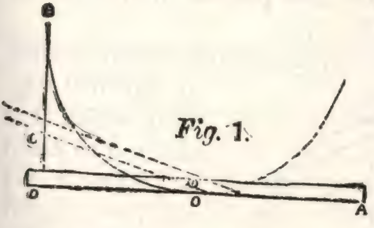
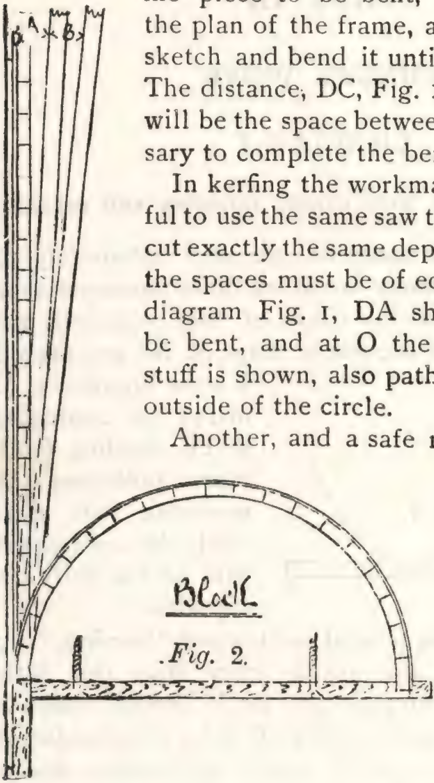


Fig. 1.

First of all, I give several methods of "kerfing," for few things puzzle the novice more than this little problem. Let us suppose any circle around which it is desired to bend a piece of stuff to be 2 inches larger on the outside than on the inside, or in other words, the veneer is to be 1 inch thick, then take out as many saw kerfs as will measure 2 inches. Thus, if a saw cuts a kerf one thirty-second of an inch in width, then it will take 64 kerfs in the half circle to allow for the

veneer to bend around neatly. The piece being placed in position and bent, the kerfs will exactly close.



.Fig. 2.

Another way is to saw one kerf near the center of the piece to be bent, then place it on the plan of the frame, as indicated in the sketch and bend it until the kerf closes. The distance, DC, Fig. 1, on the line DB, will be the space between the kerfs necessary to complete the bending.

In kerfing the workman should be careful to use the same saw throughout, and to cut exactly the same depth every time, and the spaces must be of equal distance. In diagram Fig. 1, DA shows the piece to be bent, and at O the thickness of the stuff is shown, also path of the inside and outside of the circle.

Another, and a safe method of kerfing is shown at Fig. 2, in which it is desired to bend a piece as shown, and which is intended to be secured at the ends. Up to A is the piece to be treated. First gauge a line on about one-eighth inch back from the face edges, and try how far it will yield when the first cut is made up to the gauge line, being cut perfectly straight through from side to side, then place the work

on a flat board and try it gently until the kerf closes, and it goes as far as is shown at A, which is the first cut, B representing the second. Those are the distances the kerfs require to be placed apart to complete the curve. Try the work as it progresses. This eases the back of it and makes it much easier done when the whole cuts are finished. Now make certain that the job will fold to the curve, then fill them all with hot glue and proceed to fix. The plan shown here is a half semi, and may be in excess of what is wanted, but the principle holds good.

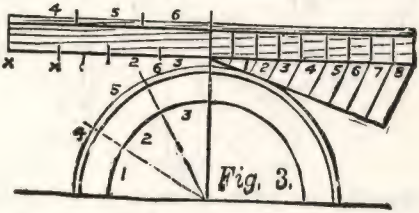


Fig. 3.

Another method is shown at Fig. 3 for determining the number and distances apart of the saw kerfs required to bend a board round a corner. The board is first drawn in position and a half of it divided into any number of equal parts by radii, as 1, 2, 3, 4, 5, 6. A straight piece is then marked off to correspond with the divisions on the circular one. By this it is seen that the part XX must be cut away by saw kerfs in order to let the board turn round. It therefore depends upon the thickness of the saw for the number of kerfs, and when that is known the distances apart can be determined as shown on the right in the figure. Here eight kerfs are assumed to be requisite.

To make a kerf for bending round an ellipse, such as that shown at Fig. 4, proceed as shown, CC and OO being the distances for the kerfs; 2 to 2 and 2 to 3 are the lengths of the points EF, while BB is the length of the

points EE, making the whole head piece in one. In case it is necessary to joint D, leave the ends about 8 inches longer than is necessary, as shown by N in the

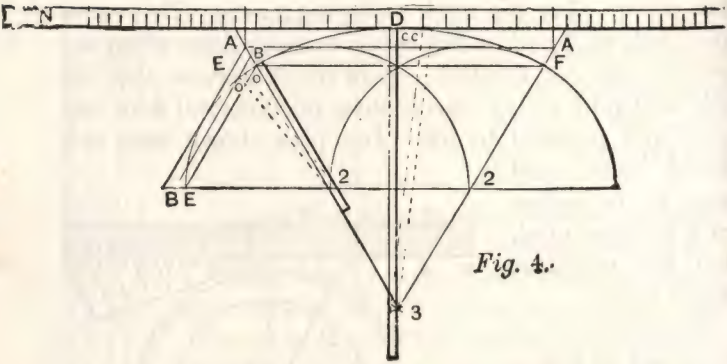
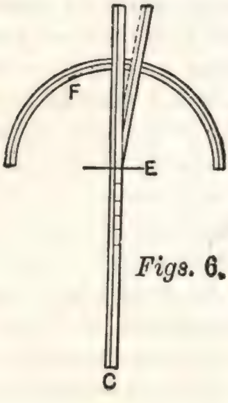


Fig. 4.

sketch, so that should a breakage occur this extra length may be utilized.

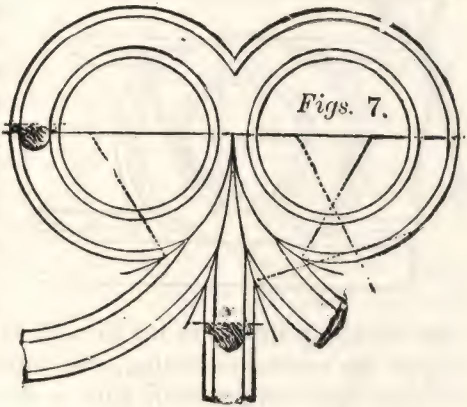
It is sometimes necessary to bend thick stuff around work that is on a rake, and when this is required, all that is necessary is to run in the kerfs the angle of the rake whatever that may be, as shown at Fig. 5. This rule holds good for all pitches or rakes. Fig. 6 shows a very common way of obtaining the distance to place the kerfs. The piece to be kerfed is shown at C; now make one at E; hold firm the lower part of C and bend

Fig. 5.



Figs. 6.

the upper end on the circle F until the kerf is closed. The line started at E and cutting the circumference of the circle indicates at the circumference the distance the saw kerfs will be apart. Set the dividers to this space, and beginning at the center cut, space the piece to be kerfed both ways. Use the same saw in all cuts and let it be clean and keen, with all dust well cleaned out.


Figs. 7.

To miter mouldings, where straight lines must merge into lines having a curvature as in Figs. 7 and 8: In all cases, where a straight moulding is intersected with a curved moulding of the same profile at whatever angle, the miter is necessarily other than a straight line. The miter line is found by the intersection of lines from the several points of the profile as they occur respectively in the straight and the curved mouldings. In order to find the miter between two such mouldings, first project lines from all of the points of

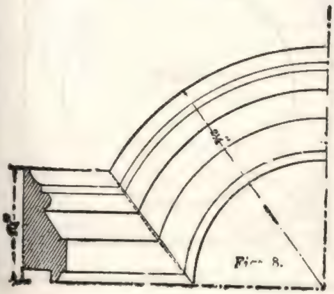


Fig. 8.

the profile indefinitely to the right, as shown in the elevation of the sketch. Now, upon the center line of the curved portion, or upon any line radiating from the center around which the curved moulding is to be carried, set off the several points of the profile, spacing them exactly the same as they are in the elevation of the straight moulding. Place one leg of the dividers at the center of the circle, bringing the other leg to each of the several points upon the curved moulding, and carry lines around the curve, intersecting each with a horizontal line from the corresponding point of the level moulding. The dotted line drawn through the intersections at the miter shows what must be the real miter line.

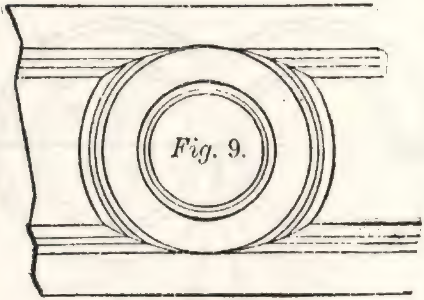


Fig. 9.

Another odd mitering of this class is shown in Fig. 9. In this it will be seen that the plain faces of the stiles and circular rail form junctions, the mouldings all being mitered. The miters are curved in order

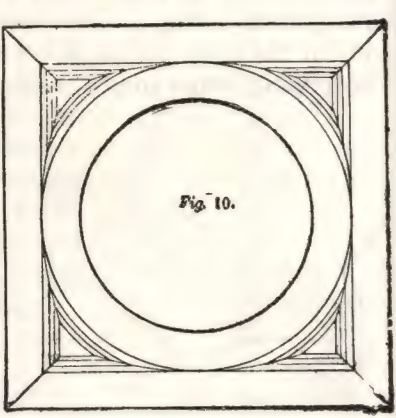


Fig. 10.

to have all the members of the mouldings merge in one another without overwood. Another example is shown at Fig. 10, where the circle and mouldings make a series of panels. These examples are quite sufficient to enable the workman to deal effectively with every problem of this kind.

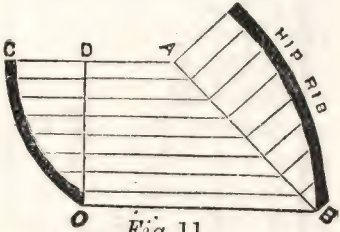
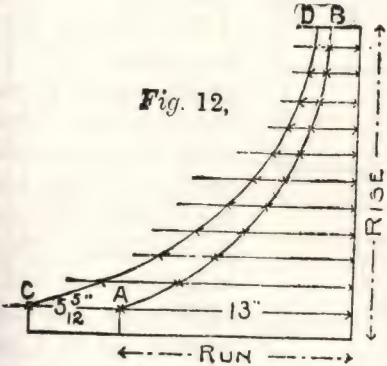


Fig. 11,

The workman sometimes finds it a little difficult to lay out a hip rafter for a veranda that has a curved roof. A very easy method of finding the curve of the hip is shown at Fig. 11. Let AB be the length of the angle or seat of hip, and CO the curve; raise perpendicular on AB, as shown, same as those on DO, and trace through the points obtained, and the thing is done.

Fig. 12,



Another simple way of finding the hip for a single curve is shown at Fig. 12; AB represents the curve given the common rafter.

Now lay off any number of lines parallel with the seat from the rise, to and beyond the curve AB, as shown, and for each inch in length of these lines (between rise and curve), add 5/12 of an inch to the same line to the left of the curve, and check. After

all lines have thus been measured, run an off-hand curve through the checks, and the curve will represent the corresponding hip at the center of its back.

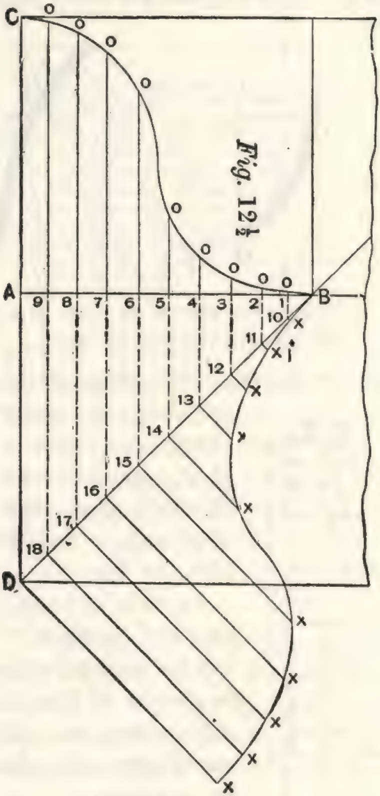


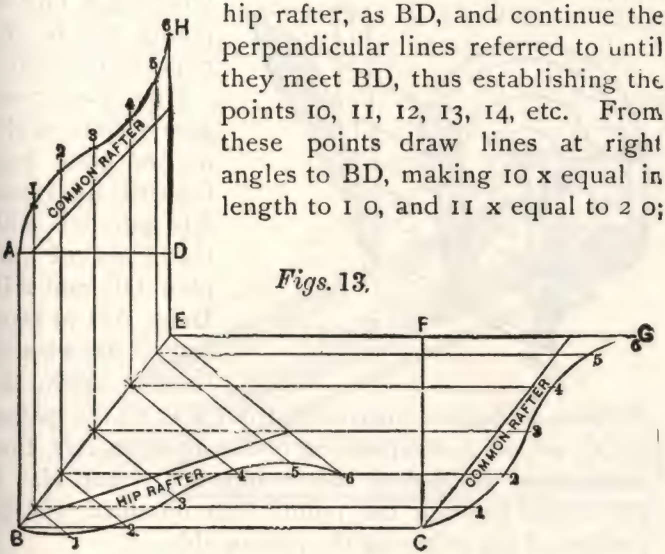
Fig. 12½

To find the bevel or backing of the hip to coincide with the plane of the common rafter, measure back on the parallel lines to the right of the curve one-half the thickness of the hip and draw another curve, which will be the lines on the side to trim to from the center of the back. A like amount must be added to the plumb cut to fit the corner of deck. Proceed in like manner for the octagon hip, but instead of adding $\frac{5}{12}$, add $\frac{1}{12}$ of an inch as before described.

[While this is worked out on a given rise and run for the rafter, the rule is applicable to any rise or run, as the workman will readily understand.]

A more elaborate system for obtaining the curve of a hip rafter, where the common rafters have an ogee or concave and convex shape, is shown at Fig. 12½. This

is a very old method, and is shown—with slight variations—in nearly all the old works on carpentry and joinery. Draw the seat of the common rafter, AB, and rise, AC. Then draw the curve of the common rafter, CB. Now divide the base line, AB, into any number of equal spaces, as 1, 2, 3, 4, 5, etc., and draw perpendicular lines to construct the curve CB, as 1 0, 2 0, 3 0, 4 0, etc. Now draw the seat of the valley, or hip rafter, as BD, and continue the perpendicular lines referred to until they meet BD, thus establishing the points 10, 11, 12, 13, 14, etc. From these points draw lines at right angles to BD, making 10 x equal in length to 1 0, and 11 x equal to 2 0;



Figs. 13.

also 12 x equal to 3 0, and so on. When this has been done draw through the points indicated by x the curve, which is the profile of the valley rafters.

Another method, based on the same principles as Fig. 12½, is shown at Fig. 13. Let ABCFED represent the plan of the roof. FCG represents the profile of the wide side of common rafter. First divide this common rafter, GC, into any number of parts—in this case 6.

Transfer these points to the miter line EB, or, what is the same, the line in the plan representing the hip rafter From the points thus established at E, erect perpendiculars indefinitely With the dividers take the distance from the points in the line FE, measuring to the points in the profile GC, and set the same off on corresponding lines, measuring from EB, thus establishing the points 1, 2, etc.; then a line traced through these points will be the required hip rafter.

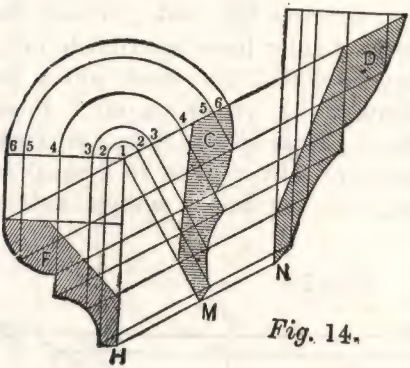


Fig. 14.

For the common rafter, on the narrow side, continue the lines from EB parallel with the lines of the plan DE and AB. Draw AD at right angles to these lines. With the dividers, as before, measuring from FE to the points in GC, set off corresponding distances from AD, thus establishing the points shown between A and H. A line traced through the points thus obtained will be the line of the rafter on the narrow side.

These examples are quite sufficient to enable the workman to draw the exact form of any rafter no matter what the curve of its face may be, or whether it is for a veranda hip, or an angle bracket, for a cornice or niche.

Another class of angular curves the workman will meet with occasionally, is that when raking mouldings are used to work in level mouldings, as for

instance, a moulding down a gable that is to miter. The figures shaded in Fig. 14 represent the moulding in its various phases and angles. Draw the outline of the common level moulding, as shown at F, in the same position as if in its place on the building. Draw lines through as many prominent points in the profile as may be convenient, parallel with the line of rake. From the same points in the moulding draw vertical lines, as shown by 1H, 2, 3, 4 and 5, etc. From the point 1, square with the lines of the rake, draw 1M,

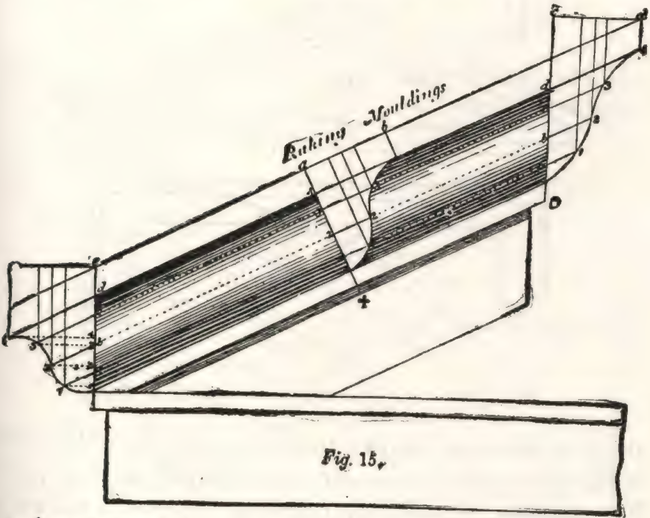


Fig. 15.

as shown, and from 1 as center, with the dividers transfer the divisions 2, 3, 4, etc., as shown, and from the points thus obtained, on the upper line of the rake draw lines parallel to 1M. Where these lines intersect with the lines of the rake will be points through which the outline C may be traced.

In case there is a moulded head to put upon a raking

gable, the moulding D shown at the right hand must be worked out for the upper side. The manner in which this is done is self-evident upon examination of the drawing, and therefore needs no special description.

A good example of a raking moulding and its applications to actual work is shown in Fig. 15, on a different scale. The ogee moulding at the lower end is the regular moulding, while the middle line, *ax*, shows the shape of the raking moulding, and the curve on

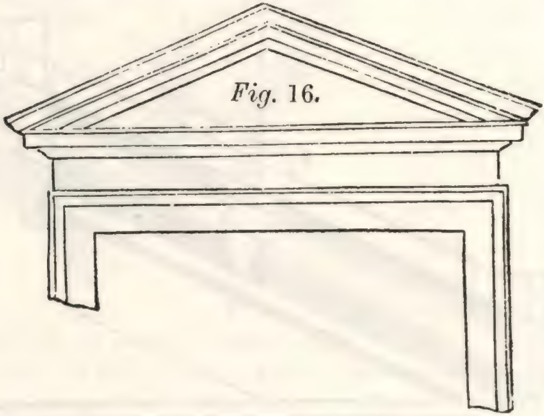


Fig. 16.

the top end, *cdo*, shows the face of a moulding that would be required to return horizontally at that point. The manner of pricking off these curves is shown by the letters and figures.

At Fig. 16 a finished piece of work is shown, where this manner of work will be required, on the returns.

Fig. 17 shows the same moulding applied to a curved window or door head. The manner of pricking the curve is given in Fig. 18.

At No. 2 draw any line, AD, to the center of the

pediment, meeting the upper edge of the upper fillet in D, and intersecting the lines AAA, *aaa*, *bbb* *ccc*,

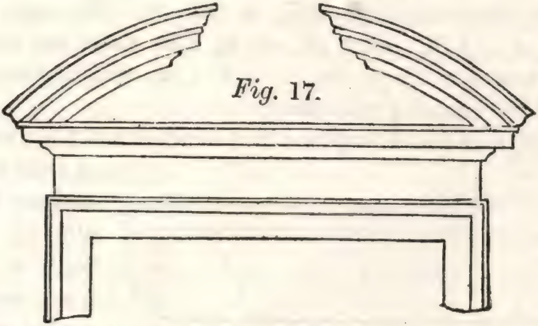


Fig. 17.

BBB in A, *a*, *b*, *c*, B, E. From these points draw lines *aa*, *bb*, *cc*, BB, EE, tangents to their respective arcs;

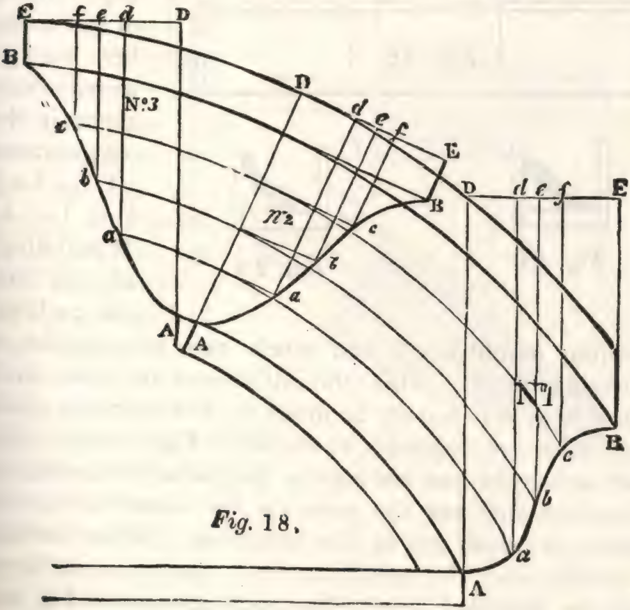


Fig. 18.

on the tangent line DE, from D, make D*d*, D*e*, D*f*, **DE**, respectively equal to the distances D*d*, D*e*, D*f*, **DE** on the level line **DE**, at No. 1. Through the points *d*, *e*, *f*, E, draw *da*, *eb*, *fc*, EB, then the curve drawn through the points A, *a*, *b*, *c*, B, will be the section of the circular moulding.

Sometimes mouldings for this kind of work are made of thin stuff, and are beveled on the back at the bottom in such a manner that the top portion of the member hangs over, which gives it the appearance of being solid. Mouldings of this kind are called "spring mouldings," and much care is required in mitering them. This should always be done in a miter box, which must be made for the purpose; often two boxes are required, as shown in Figs. 19-22. The cuts across the box are regular miters, while the angles down the side are the same as the down cut of the rafter, or plumb cut of the moulding. When the box is ready, place the mouldings in it upside down, keeping the moulded side to the front, as seen in Fig. 20.

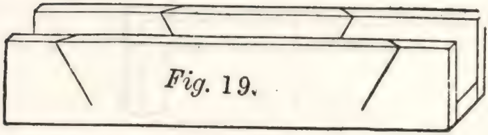


Fig. 19.

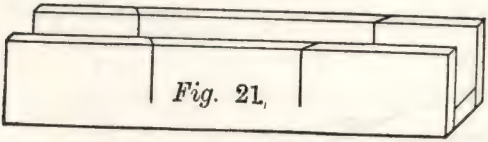


Fig. 21.

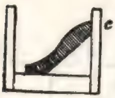


Fig. 20

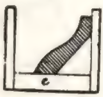


Fig. 22.

making sure that the level of the moulding at *c* fits close to the side of the box.

To miter the rake mouldings together at the top, the box shown in Fig. 21 is used. The angles on the top of the box are the same as the down bevel at the top of the rafter, the sides being sawed down square. Put the moulding in the box, as shown in Fig. 22, keeping the bevel at *c* flat on the bottom of the box, and having the moulded side to the front, and the miter for the top is cut, which completes the moulding for one side of the gable. The miter for the top of the moulding for the other side of the gable may then be cut.

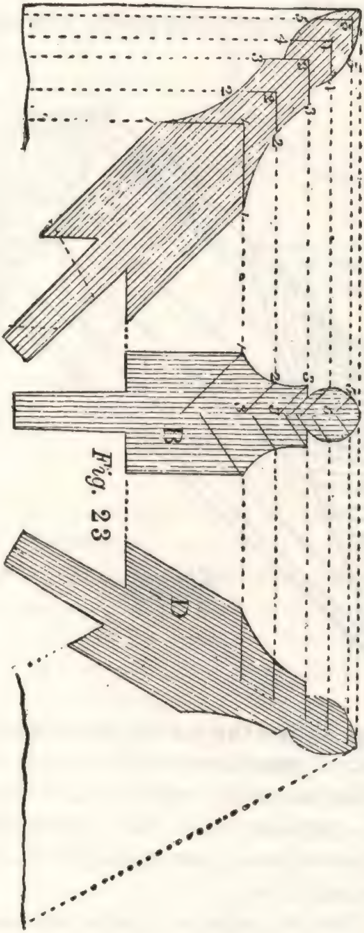


Fig. 23

When the rake moulding is made of the proper form these boxes are very convenient; but a great deal of the machine-made mouldings are

not of the proper form to fit. In such cases the moulding should be made to suit, or they come bad; although many use the mouldings as they come from the factory, and trim the miters so as to make them do.

The instructions given, however, in Figs. 13, 14, 15 and 18 will enable the workman to make patterns for what he requires.

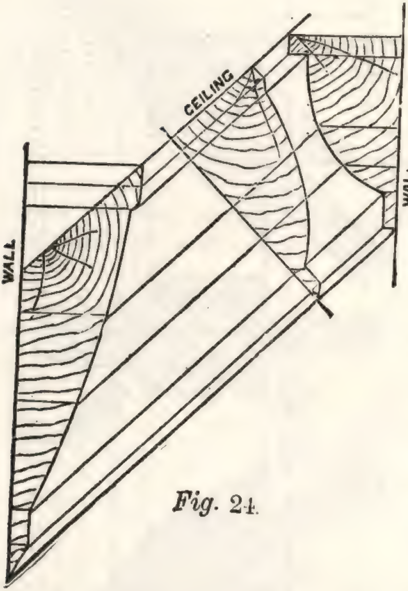


Fig. 24.

While the "angle bar" is not much in vogue at the present time, the methods by which it is obtained, may be applied to many purposes, so it is but proper the method should be embodied in this work. In Fig. 23, B is a common sash bar, and C is the angle bar of the same thickness. Take the raking projection, 1 1, in C, and set the foot of your compass in 1 at B, and cross the middle of the bar at the other 1; then draw the points 2, 2, 3, 3, etc., parallel to 1 1, then prick your bar at C from the ordinates so drawn at B, which, when traced, will give the angle bar.

This is a simple operation, and may be applied to

many other cases, and for enlarging or diminishing mouldings or other work.

The next figure, 24, gives the lines for a raking moulding, such as a cornice in a room with a sloping ceiling. As may be seen from the diagram the three sections shown are drawn equal in thickness to miter at the angles of the room.

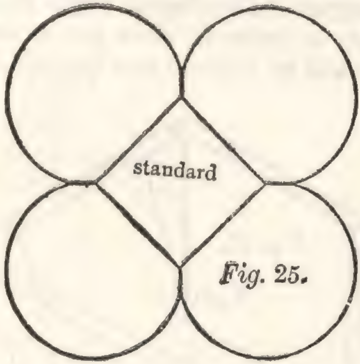


Fig. 25.

The construction should be easily understood. When a straight moulding is mitered with a curved one the line of miter is sometimes straight and someimes curved, as seen at Fig. 18, and when the mouldings are all curved the miters are also straight and curved, as shown in previous examples.

If it is desired to make a cluster column of wood, it is first necessary to make a standard or core, which must have as many sides as there are to be faces of columns.

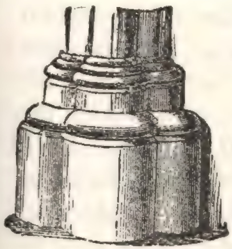


Fig. 26.

Fig. 25 shows how the work is done. This shows a cluster of four columns, which are nailed to a square standard or core. Fig. 26 shows the base of a clustered column. These are blocks turned in the lathe, requiring four of them for each base, which are cut and mitered as shown in Fig. 25. The cap, or capital, is, of course, cut in the same manner.

Laying out lines for hopper cuts is often puzzling, and on this account I will devote more space to this subject than to those requiring less explanations.

Fig. 27 shows an isometric view of three sides of a hopper. The fourth side, or end, is purposely left out, in order to show the exact build of the hopper. It will be noticed that AC and EO show the end of the work as squared up from the bottom, and that BC shows the gain of the splay or flare. This gives the idea of what a hopper is, though the width of side and amount of flare may be any measurement that may be decided upon. The difficulty in this work is to get the proper lines for the miter and for a butt cut.

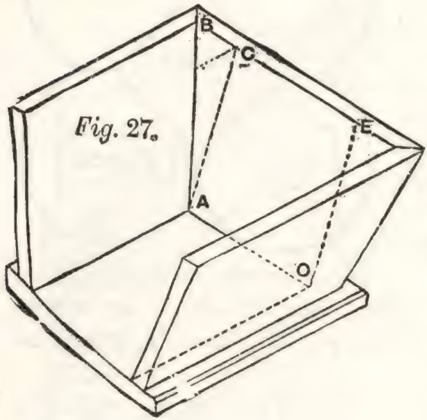


Fig. 27.

Let us suppose the flare of the sides and ends to be as shown at Fig. 28, though any flare or inclination will answer equally well. This diagram and the plan exhibit the method to be employed, where the sides and ends are to be mitered together. To obtain the bevel to apply for the side cut, use A′ as center, B′ as radius, and CDF′ parallel to BF. Project from B to D parallel to XY. Join AD, which gives the bevel required, as shown. If the top edge of the stuff is to be horizontal, as shown at B′G′, the bevel to apply to the edge will be simply as shown in plan by BG; but if

the edge of the stuff is to be square to the side, as shown at B′C′, Fig. 29, the bevel must be obtained as follows: Produce EB′ to D′, as indicated, Fig. 29. With B as center, describe the arc from C′, which gives the point D. Project down from D, making DF

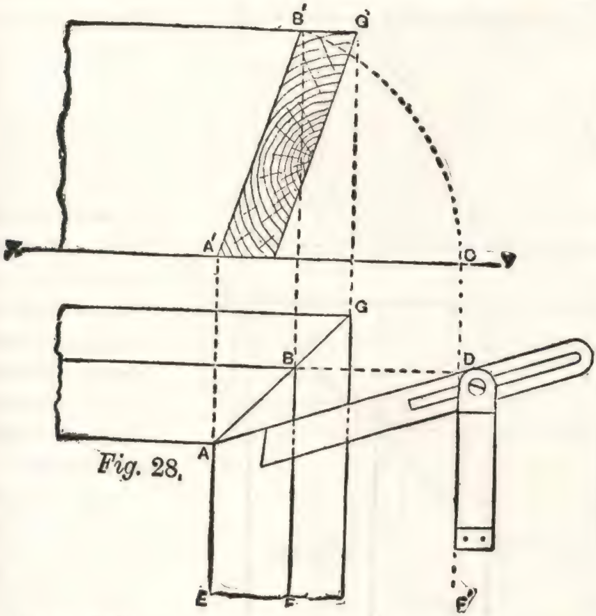


Fig. 28.

parallel to CC, as shown. Project from C parallel to XY. This will give the point D. Join BD, and this will give the bevel line required. At A, Fig. 31, is shown the application of the bevel to the side of the stuff, and at B the application of the bevel to the edge of the stuff. When the ends butt to the sides, as indicated at H, Fig. 30, the bevel, it will be noticed, is obtained in a similar manner to that shown at Fig. 28. It is not often that simply a butt joint is used between

the ends and sides, but the ends are usually housed into the sides, as indicated by the dotted lines shown at H, Fig. 30.

Another system, which was first taught by the celebrated Peter Nicholson, and afterwards by Robert Riddell, of Philadelphia, is explained in the following: The illustration shown at Fig. 32 is intended to show how to find the lines for cutting butt joints for a hopper. Construct a right angle, as A, B, C, Fig. 32, continue A, B past K. From K, B make the inclination of the sides of the hopper, 2, 3.

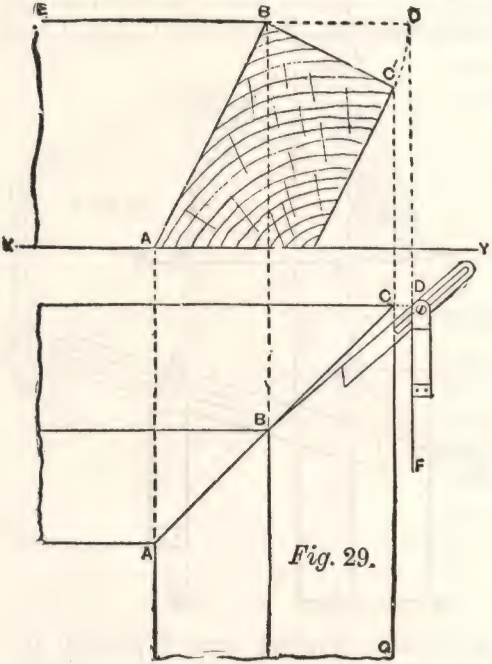


Fig. 29.

Draw 3, 4 at right angles with 3, 2; take 3 as center, and strike an arc touching the lower line, cutting in 4. Draw from 4, cutting the miter line in 5; from 5 square draw a line cutting in 6, join it and B; this gives bevel W, as the direction of cut on the surface of sides. To find the butt joint, take any two points, A, C, on the

right angle, equally distant from B, make the angle B, K, L, equal that of 3, K, L, shown on the left; from B draw through point L; now take C as a center, and strike an arc, touching line BL. From A draw a line touching the arc at H, and cutting the extended line through B in N, thus fixing N as a point. Then by drawing from C through N, we get the bevel X for the butt joint. Joints on the ends of timbers running horizontally in tapered framed structures, when the plan is square and the inclinations equal, may be found by this method.

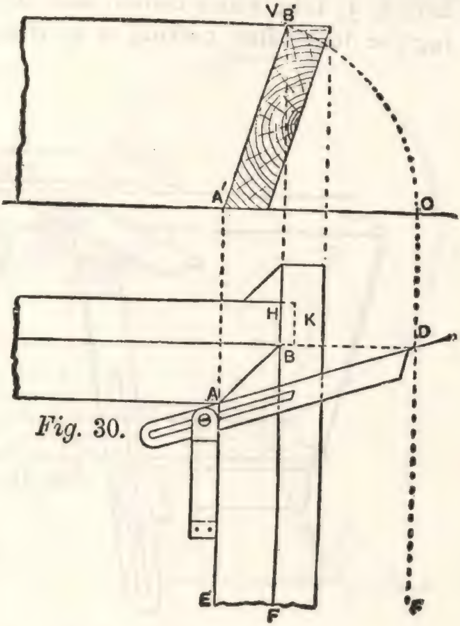


Fig. 30.

The backing of a hip rafter may also be obtained by this method, as shown at J, where the pitch line is used as at 2, 3, which would be the inclination of the roof.

The solution just rendered is intended only for hoppers having right angles and equal pitches or splays, as hoppers having acute or obtuse angles must be treated in a slightly different way.

Let us suppose a butt joint for a hopper having an

acute angle, such as shown at A, B, C, Fig. 33, and with an inclination as shown at 2, 3. Take any two points, A, C, equally distant from B. Join A, C, bisect this line in P, draw through P, indefinitely. Find a bevel for the side cut by drawing 3, 4, square with 2, 3; take 3 as a center, and strike an arc, touching the lower line cutting in 4; draw from 4, cutting

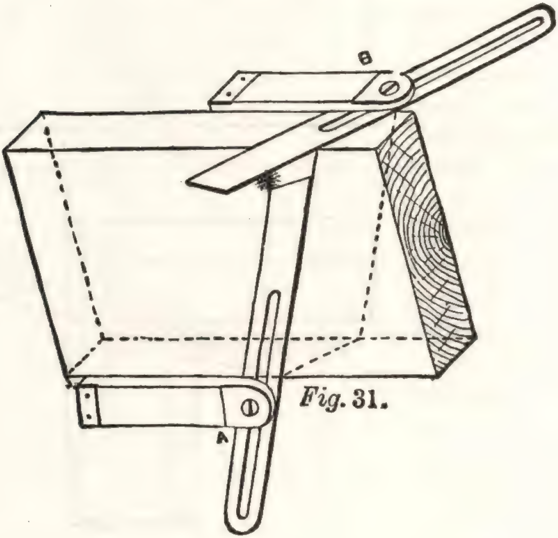


Fig. 31.

the miter line in 5, and from it square draw a line cutting in 6. Join 6, B, this gives bevel W, for direction of cut on the surface of inclined sides.

The bevel for a butt joint is found by drawing C, 8, square with A, B; make the angle 8, K, L, equal that of 3, K, L, shown on the left. Draw from 8 through point L; take C as a center and strike an arc touching the line 8, L; draw from A, touching the arc at D, cutting

the line from P, in D, making it a point, then by drawing from C, through D, we get the bevel X for the butt joint.

As stated regarding the previous illustration, the backing for a hip in a roof having the pitch as shown at 2, 3, may be found at the bevel J. The same rule

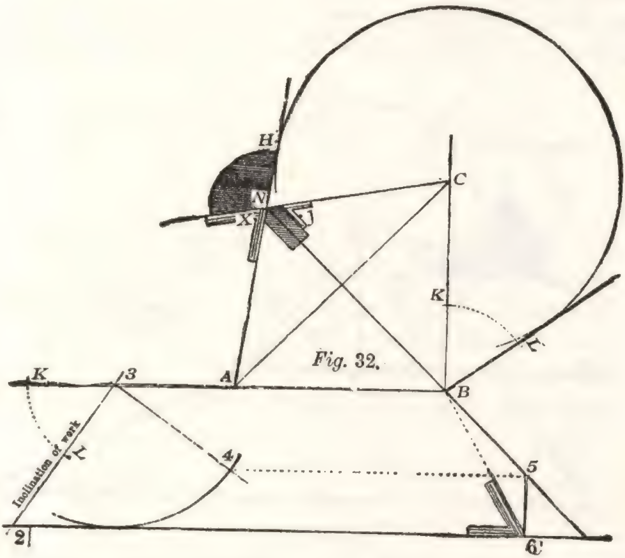


Fig. 32.

also applies to end joints on timbers placed in a horizontal double inclined frame, having an acute angle same as described.

Having described the methods for finding the butt joints in right-angled and acute-angled hoppers, it will be proper now to define a method for describing an obtuse-angled hopper having butt joints.

Let the inclination of the sides of the hopper be

exhibited at the line 2, 3, and the angle of the obtuse corner of the hopper at A, B, C, then to find the joint, take any two points, A, C, equally distant from B, join these points, and divide the line at P. Draw through P and B, indefinitely. At any distance below the side A, B, draw the line 2, 6; make 3, 4, square with the inclination. From 3, as a center, describe an arc, touching the lower line and cutting in 4; from 4 draw to cut the miter line in 5, and from it square

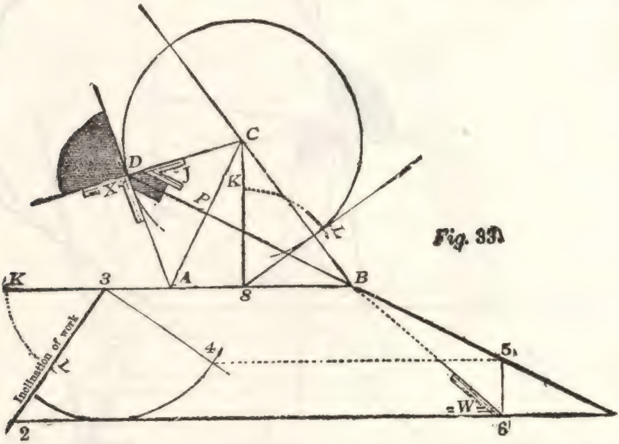


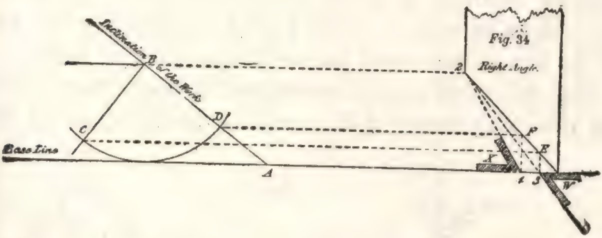
Fig. 33

down a line cutting in 6, join 6, B, and we get the bevel W, for cut on surface sides.

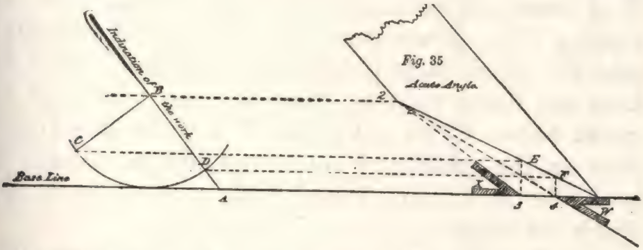
The bevel for the butt joint is found by drawing C, D, square with B, A, and making the angle D, K, L equal to that of 3, K, L on the left. From C, as a center, strike an arc, touching the line D, L; then from A draw a line touching the arc H. This line having cut through P, in N, fixes N as a point, so that by drawing C through N an angle is determined, in which is bevel X for the butt joint.

To obtain the levels or miters is a simple matter to one who has mastered the foregoing, as evidenced by the following:

Fig. 34 shows a right-angled hopper; its sides may stand on any inclination, as AB. The miter line,



2, W, on the plan, being fixed, draw B, C square with the inclination. Then from B, as center, strike an arc, touching the base line and cutting in CD. From CD draw parallel with the base line, cutting the miters in F and E; and from these points square down the lines, cutting in 3 and 4. From 2 draw through 3; this gives



bevel W for the direction of cut on the surface sides. Now join 2, 4, this gives bevel X to miter the edges, which in all cases must be square, in order that bevels may be properly applied.

Fig. 35 shows a plan forming an acute-angled hop-

per, the miter line being 2, W. The sides of this plan are to stand on the inclination AB. Draw BC square with the inclination, and from B, as center, strike an arc, touching the base line and cutting in CD. Draw from CD, cutting the miter line at E and F; from these points square down the lines, cutting in 3 and 4. From 2 draw through 4, which will give bevel W to miter the edges of sides. Now join 2, 3, which gives bevel X for the direction of cut on the surface of sides.

Fig. 36 shows an obtuse-angled hopper, its miter line on the plan being 2 W, and the inclination of sides

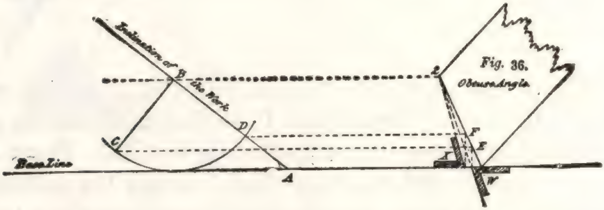


Fig. 36.

AB. Draw BC square with the inclination, and from B as center strike an arc, touching the base line and cutting CD. Draw from CD, cutting the miter in F and E. From these points square down the lines, cutting the base; then by drawing from 2 through the point below E, we get bevel W for the direction of cuts on the surface of sides, and in like manner the point below F being joined with 2, gives bevel X to miter the edges.

It will be noticed that the cuts for the three different angles are obtained on exactly the same principle, without the slightest variation, and so perfectly simple as to be understood by a glance at the drawing. The workman will notice that in each of the angles a

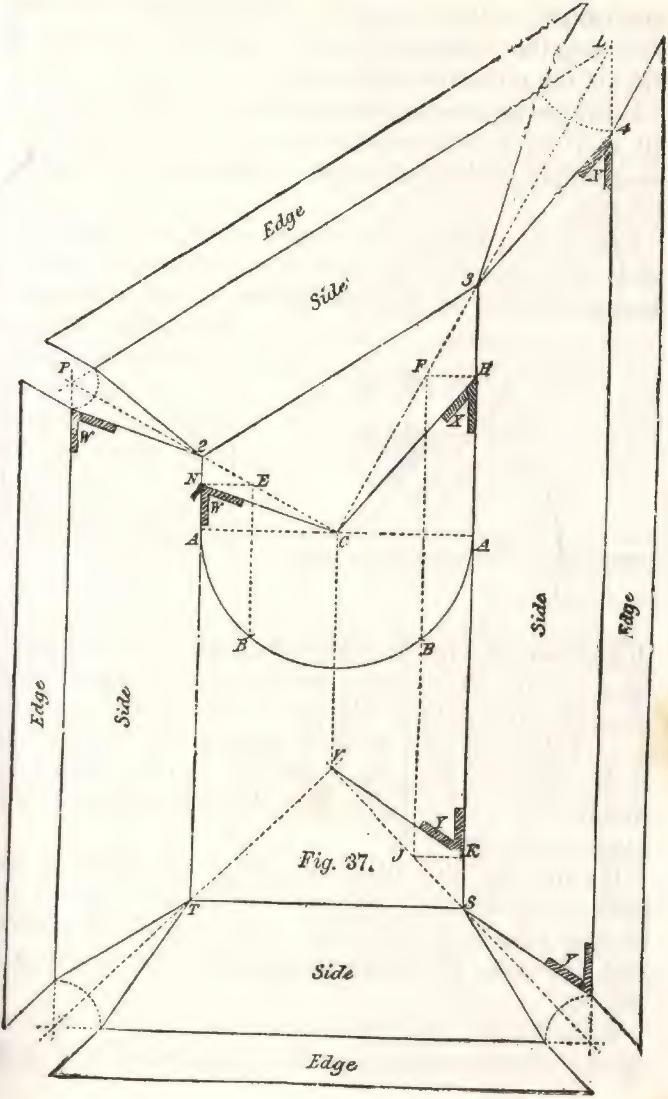

Edge
Side
3
L
4
P
F
H
W
X
2
N
E
W
A
C
A
B
B
Side
Edge
Edge
Side
V
Y
J
K
T
S
Side
Y
Edge

Fig. 37.

line from C, cutting the miter, invariably gives a direction for the surface of sides, and the line from D directs the miter on their edges.

Unlike many other systems employed, this one meets all and every condition, and is the system that has been employed by high class workmen and millwrights for ages.

One more example on hopper work and I am done with the subject: Suppose it is desired to build a hopper similar to the one shown at Fig. 37, several new conditions will be met with, as will be seen by an examination of the obtuse and acute angles, L and P. In order to work this out right make a diagram like

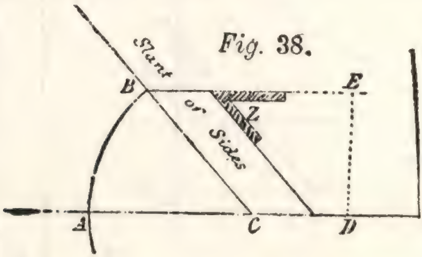


Fig. 38.

that shown at Fig. 38, where the line AD is the given base line on which the slanting side of hopper or box rises at any angle to the base line, as CB, and the total height of the work is represented by the line B, E. By this diagram it will be seen that the horizontal lines or bevels of the slanting sides are indicated by the bevel Z.

Having got this diagram, which of course is not drawn to scale, well in hand, the ground plan of the hopper may be laid down in such a shape as desired, with the sides, of course, having the slant as given in Fig 38.

Take T2, 3S, Fig. 37, as a part of the plan, then set off the width of sides equal to C, B, as shown in Fig. 38.

These are shown to intersect at P, L above; then draw lines from P, L through 2, 3, until they intersect at C, as the dotted lines show. Take C as a center, and with the radius A, describe the semi-circle A, A, and with the same radius transferred to C, Fig. 38, describe the arc A, B, as shown. Again, with the same radius, set off A, B, A, B on Fig. 37, cutting the semi-circle at B, as shown. Now draw through B, on the right, parallel with S, 3, cutting at J and F; square over F, H and J, K, and join H, C; this gives bevel X, as the cut for face of sides, which come together at the angle shown at 3. The miters on the edge of stuff are parallel with the dotted line, L, 3. This is the acute corner of the hopper, and as the edges are worked off to the bevel 2, as shown in Fig. 38, the miter must be correct.

Having mastered the details of the acute corner, the square corner at S will be next in order. The first step is to join K, V, which gives the bevel Y, for the cut on the face of sides on the ends, which form the square corners. The method of obtaining these lines is the same as that explained for obtaining them for the acute-angled corner, as shown by the dotted lines, Fig. 35. As the angles, S, T, are both square, being right and left, the same operation answers both, that is, the bevel Y does for both corners.

Coming to the obtuse angle, P, 2, we draw a line B, E, on the left, parallel with A, 2, cutting at E, as shown by dotted line. Square over at E, cutting T, A, 2 at N; join N, C, which will give the bevel W, which is the angle of cut for face of sides. The miters on edges are found by drawing a line parallel with P, 2.

In this problem, like Fig. 34, every line necessary to the cutting of a hopper after the plan as shown by

the boundary lines 2, 3, T, S, is complete and exhaustive, but it must be understood that in actual work the spreading out of the sides, as here exhibited, will not be necessary, as the angles will find themselves when the work is put together. When the plan of the base—which is the small end of the hopper in this case—is given, and the slant or inclination of the sides known, the rest may be easily obtained. In order to become thoroughly conversant with the problem, I would advise the workman to have the drawing made on cardboard, so as to cut out all the outer lines, including the open corners, which form the miters, leaving the whole piece loose. Then make slight cuts in the back of the cardboard, opposite the lines 2, 3, S, T, just deep enough to admit of the cardboard being bent upwards on the cut lines without breaking. Then run the knife along the lines, which indicates the edges of the hopper sides. This cut must be made on the face side of the drawing, so as to admit of the edges being turned downwards. After all cuts are made raise the sides until the corners come closely together, and let the edges fall level, or in such a position that the miters come closely together. If the lines have been drawn accurately and the cuts made on the lines in a proper manner, the work will adjust itself nicely, and the sides will have the exact inclination shown at Fig. 38, and a perfect model of the work will be the result.

This is a very interesting problem, and the working out of it, as suggested, cannot but afford both profit and pleasure to the young workman.

From what has preceded, it must be evident to the workman that the lines giving proper angles and bevels for the corner post of a hopper must of neces-

sity give the proper lines for the corner post for a pyramidal building, such as a railway tank frame, or any similar structure. True, the position of the post is inverted, as in the hopper, its top falls outward, while in the timber structure the top inclines inward; but this makes no difference in the theory, all the operator has to bear in mind is that the hopper in this case is reversed—inverted. Once the proper shape of the corner post has been obtained, all other bevels can readily be found, as the side cuts for joists and braces can be taken from them. A study of these two figures in this direction will lead the student up to a correct knowledge of tapered framing.

CHAPTER II

COVERING SOLIDS, CIRCULAR WORK, DOVETAILING AND STAIRS

There are several ways to cover a circular tower roof. Some are covered by bending the boarding around

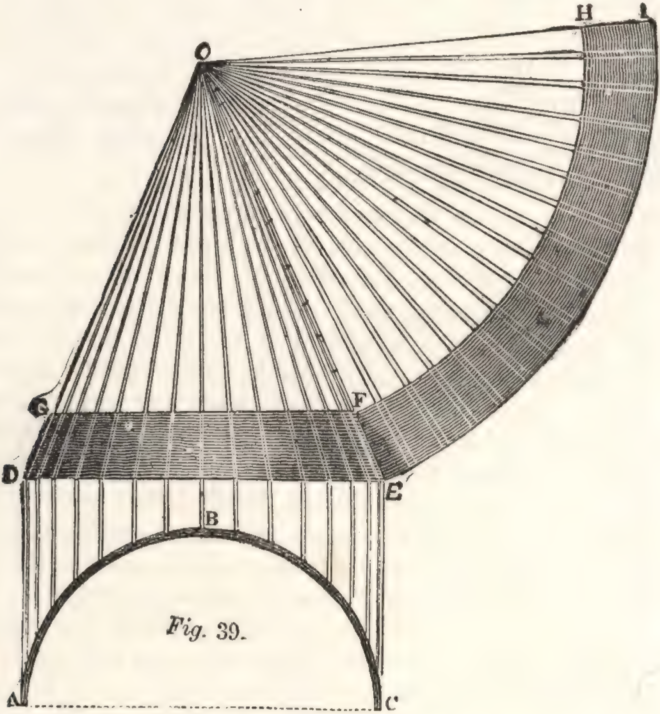


Fig. 39.

them, while others have the joints of the covering vertical, or inclined. In either case, the boarding has to be cut to shape. In the first instance, where the joints

are horizontal, the covering must be curved on both edges.

At Fig. 39 I show a part plan, elevation, and development of a conical tower roof. ABC shows half the plan; DO and EO show the inclination and height of the tower, while EH and EI show the development of the lower course of covering. This is obtained by using O as a center, with OE as radius, and striking the curve EI, which is the lower edge of the board, and corresponds to DE in the elevation. From the same center O, with radius OF, describe the curve FH, which is the joint GF on the elevation. The board, EFHI, may be any convenient width, as may also the other boards used for covering, but whatever the width decided upon, that same width must be continued throughout that course. The remaining tiers of covering must be obtained in the same way. The joints are radial lines from the center O. Any convenient length of stuff over the distance of three ribs, or rafters, will answer. This solution is applicable to many kinds of work. The

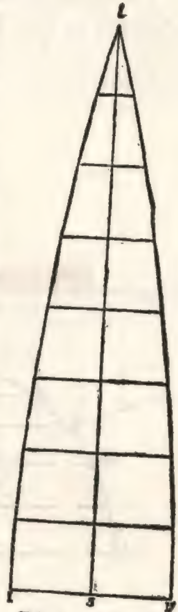


Fig. 40.

rafters in this case are simply straight scantlings; the bevels for feet and points may be obtained from the diagram. The shape of a "gore," when such is required, is shown at Fig. 40, IJK showing the base, and L the top or apex. The method of getting it out will be easily understood by examining the diagram. When "gores" are used for covering it will be necessary

to have cross-ribs nailed in between the rafters, and these must be cut to the sweep of the circle, where they are nailed in, so that a rib placed in half way up will require only to be half the diameter of the base, and the other ribs must be cut accordingly.

To cover a domical roof with horizontal boarding we proceed in the manner shown in Fig. 41, where ABC

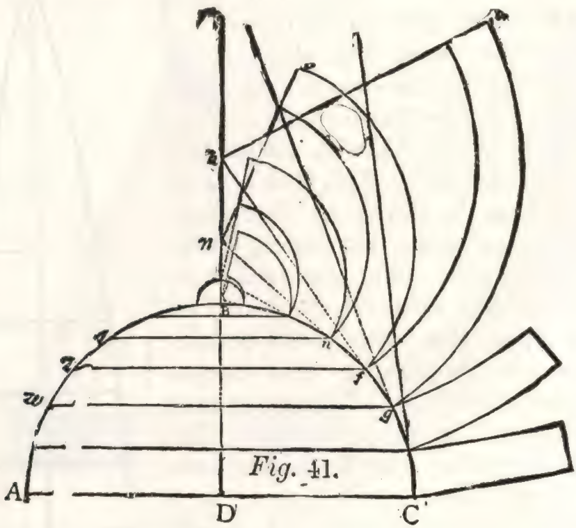


Fig. 41.

is a vertical section through the axis of a circular dome, and it is required to cover this dome horizontally. Bisect the base in the point D, and draw DBE perpendicular to AC, cutting the circumference in B. Now divide the arc, BC, into equal parts, so that each part will be rather less than the width of a board, and join the points of division by straight lines, which will form an inscribed polygon of so many lines; and through these points draw lines parallel to

the base AC, meeting the opposite sides of the circumference. The trapezoids formed by the sides of the polygon and the horizontal lines may then be regarded as the sections of so many frustrums of cones; whence results the following mode of procedure: Produce, until they meet the line DE, the lines FG, etc., forming the sides of the polygon. Then to describe a board which corresponds to the surface of one of the zones, as FG, of which the trapezoid is a section from

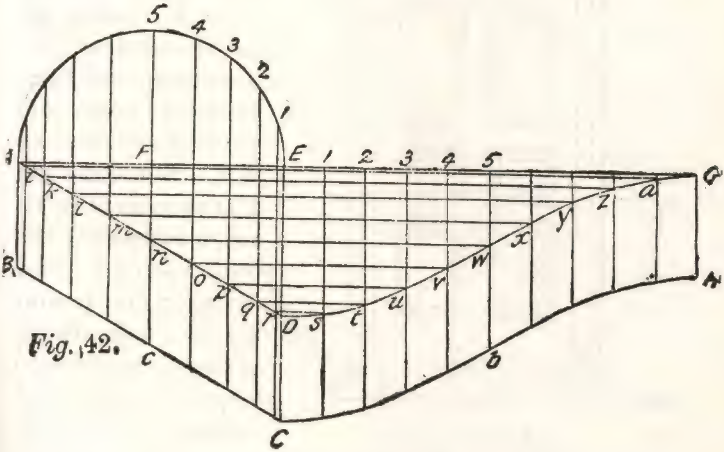


Fig. 42.

the point E, where the line FG produced meets DE, with the radii EF, EG describe two arcs and cut off the end of the board K on the line of a radius EK. The other boards are described in the same manner.

There are many other solids, some of which it is possible the workman may be called upon to cover, but as space will not admit of us discussing them all, we will illustrate one example, which includes within itself the principles by which almost any other solid

may be dealt with. Let us suppose a tower, having a domical roof, rising from another roof having an inclination as shown at BC, Fig. 42, and we wish to board it with the joints of the boards on the same inclination as that of the roof through which the tower rises. To accomplish this, let A, B, C, D, Fig. 42, be the seat of the generating section; from A draw AG perpendicular to AB, and produce CD to meet it in E; on A, E describe the semi-circle, and transfer its perimeter to E, G by dividing it into equal parts, and setting off corresponding divisions on E, G. Through the divisions of the semi-circle draw lines at right angles to AE, producing them to meet the

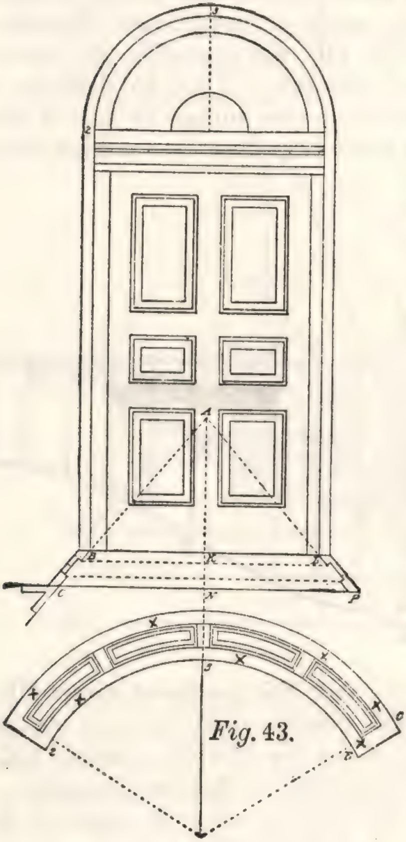


Fig. 43.

lines A, D and B, C in *i, k, l, m,* etc. Through the divisions on E, G, draw lines perpendicular to them, then through the intersections of the ordinates of the

semi-circle, with the line AD draw the lines *i*, *a*, *k*, *z*, *l*, *y*, etc., parallel to AG, and where these intersect the perpendiculars from EG, in points *a*, *z*, *y*, *x*, *w*, *v*, *u*, etc., trace a curved line, GD, and draw parallel to it the curved line HC; then will DC, HG be the development of the covering required.

Almost any description of dome, cone, ogee or other solid may be developed, or so dealt with under the principle as shown in the foregoing, that the workman, it is hoped, will experience but little difficulty in laying out lines for cutting material to cover any form of curved roof he may be confronted with.

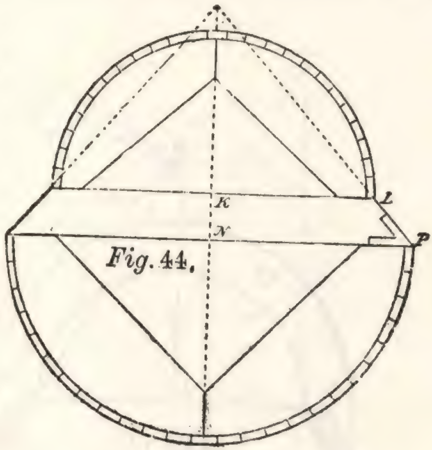


Fig. 44.

Another class of covering is that of making soffits for splayed doors or windows having circular or segmental heads, such as shown in Fig. 43, which exhibits a door with a circular head and splayed jambs. The head or soffit is also splayed and is paneled as shown. In order to obtain the curved soffit, to show the same splay or angle, from the vertical lines of the door, proceed as follows: Lay out the width of the doorway, showing the splay of the jambs, as at C, B and L. P; extend the angle lines, as shown by the dotted lines, to A, which gives A, B as the radius of the

inside curve, and A, C as radius of the outside curve. These radii correspond to the radii A, B and A, C in Fig. 43; the figure showing the flat plan of the paneled soffit complete. To find the development, Fig. 43, get the stretch-out of the quarter circle 2 and 3, shown in the elevation at the top of the doorway, and

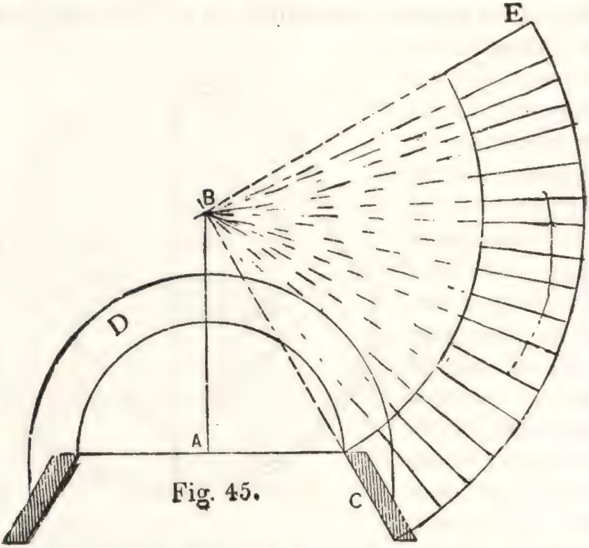


Fig. 45.

make 2, 3 and 3B, Fig. 43, equal to it, and the rest of the work is very simple.

If the soffit is to be laid off into panels, as shown at Fig. 44, it is best to prepare a veneer, having its edges curved similar to those of Fig. 43, making the veneer of some flexible wood, such as basswood, elm or the like, that will easily bend over a form, such as is shown at Fig. 44. The shape of this form is a portion of a cone, the circle L being less in diameter than the

circle P. The whole is covered with staves, which, of course, will be tapered to meet the situation. The veneer, x, x, etc., Fig. 43, may then be bent over the form and finished to suit the conditions. If the mouldings used in the panel work are bolection mouldings, they cannot be planted in place until after the veneer is taken off the form.

This method of dealing with splayed work is applicable to windows as well as doors, to circular pews in

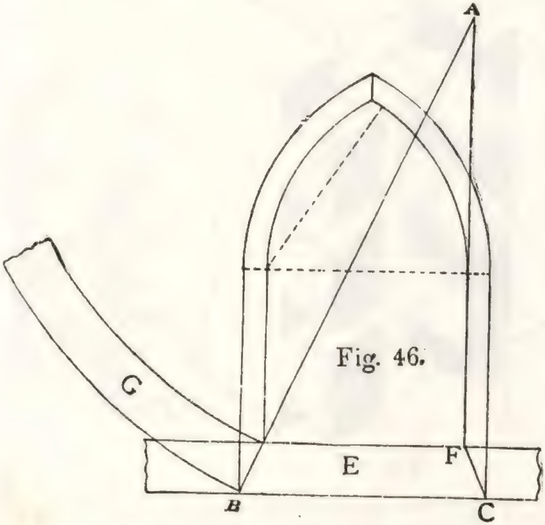


Fig. 46.

churches and many other places where splayed work is required.

A simple method of finding the veneer for a soffit of the form shown in Fig. 43 is shown at Fig. 45. The splay is seen at C, from which a line is drawn on the angle of the splay to B through which the vertical line A passes. B forms the center from which the veneer

is described. A is the center of the circular head, for both inside and outside curves, as shown at D. The radial lines centering at B show how to kerf the stuff when necessary for bending. The line E is at right angles with the line CB, and the veneer CE is the proper length to run half way around the soffit. The joints are radial lines just as shown.

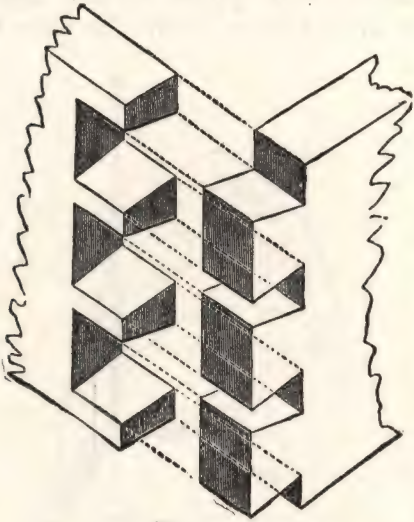


Fig. 47.

A method for obtaining the correct shape of a veneer for a gothic splayed window or door-head, is shown at Fig. 46; E shows the sill, and line BA the angle of splay. BC shows the outside of the splay; erect the inside line F to A, and this point will form the center from which to describe the curve or veneer G. This veneer will be the proper shape to bend in the soffit on either side of the window head.

The art of dovetailing is almost obsolete among carpenters, as most of this kind of work is now done by cabinet-makers, or by a few special workmen in the factories. It will be well, however, to preserve the art, and every young workman should not rest until he can do a good job of work in dovetailing; he will not find it a difficult operation.

There are three kinds of dovetailing, i.e., the common dovetail, Fig. 47; the lapped dovetail, **Fig. 48**, and the secret, or mitered dovetail, Fig. 49. These may be subdivided into other kinds of dovetailing, but there will be but little difference.

The common dovetail is the strongest, but shows the ends of the dovetails on both faces of the angles,

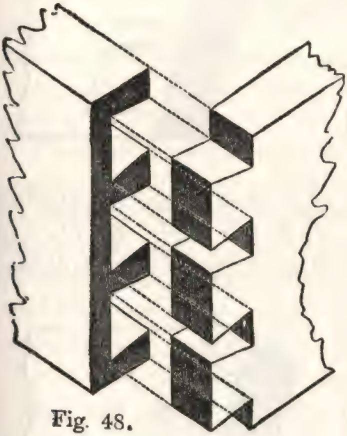


Fig. 48.

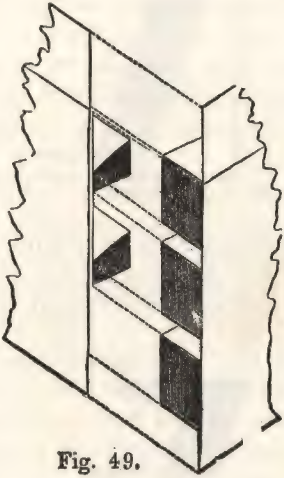


Fig. 49.

and is, therefore, only used in such places as that of a drawer, where the external angle is not seen.

The lapped dovetail, where the ends of the dovetails show on one side of the angle only, is used in such places as the front of a drawer, the side being onl seen when opened.

In the miter or secret dovetail, the dovetails are no seen at all. It is the weakest of the three kinds.

At Figs. 50 and 51 I show two methods of dovetailing hoppers, trays and other splayed work. The reference letters A and B show that when the work is together A will stand directly over B. Care must be

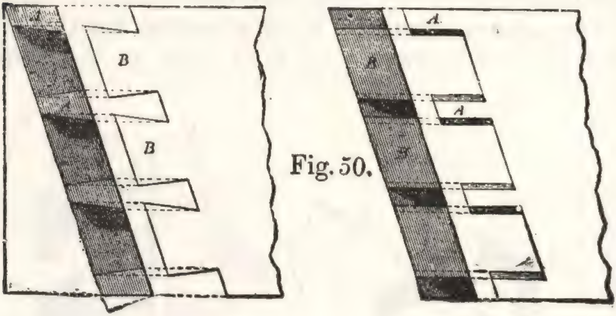


Fig. 50.

taken when preparing the ends of stuff for dovetailing for hoppers, trays, etc., that the right bevels and angles are obtained, according to the rules explained

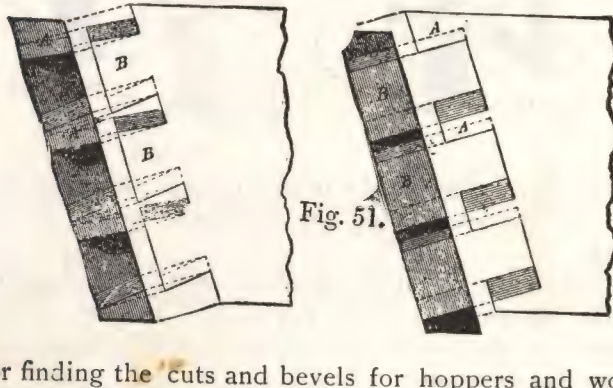


Fig. 51.

for finding the cuts and bevels for hoppers and work of a similar kind, in the examples given previously. All stuff for hopper work intending to be dovetailed

must be prepared with butt joints before the dovetails are laid out. Joints of this kind may be made common, lapped or mitered. In making the latter much skill and labor will be required.

Stair building and handrailing combined is a science in itself, and one that taxes the best skill in the market, and it will be impossible for me to do more than touch the subject, and that in such a manner as to enable the workman to lay out an ordinary straight flight of stairs. For further instructions in stair building I would refer my readers to some one or two of the many works on the subject that can be obtained from any dealer in mechanical or scientific books.

The first thing the stair builder has to ascertain is the dimension of the space the stairs are to occupy; then he must get the height, or the risers, and the width of the treads, and, as architects generally draw the plan of the stairs, showing the space they are to occupy and the number of treads, the stair builder has only to measure the height from floor to floor and divide by the number of risers and the distance from first to last riser, and divide by the number of treads. (This refers only to straight stairs.) Let us take an example: Say that we have ten feet of height and fifteen feet ten inches of run, and we have nineteen treads; thus fifteen feet ten inches divided by nineteen gives us ten inches for the width of the tread, and we have ten feet rise divided by twenty (observe here that there is always one more riser than tread), which gives us six inches for the height of the riser. The pitch-board must now be made, and as all the work has to be set out from it, care must be taken to make it exactly right. Take a piece of board, same as shown

in Fig. 52, about half an inch thick, dress it and square the side and end, A, B, C; set off the height of the rise from A to B, and the width of the tread from B to C; now cut the line AC, and the pitch-board is complete, as shown in Fig. 53. This may be done by the steel square as shown at Fig. 54. To get the width of string-boards draw the line AB, Fig. 53; add to the length of this line about half an inch more at A, the margin to be allowed, and the total will be the width of string-boards. Thus, say that we allow three inches

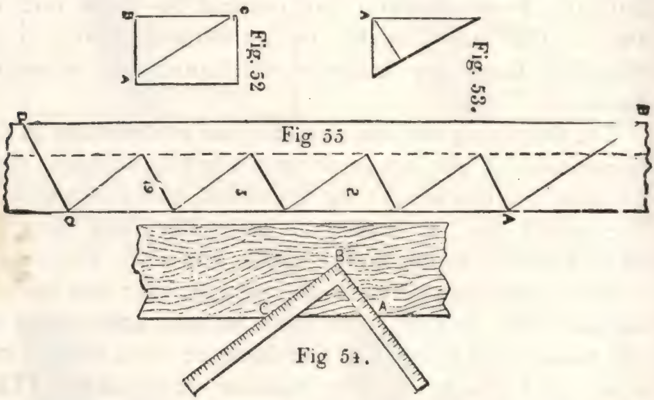


Fig. 52

Fig. 53.

Fig 55

Fig 54.

for margin, one-half inch to be left on the under side of string-board, will make the width of string-boards in this case about nine inches. Now get a plank, say one and a half inches, of any thickness that may be agreed upon, the length may be obtained by multiplying the longest side of the pitch-boards, AC, Fig. 52, by the number of risers; but as this is the only class of stairs that the length of string-boards can be obtained in this way I would recommend the beginner to practice the sure plan of taking the pitch-board and applying it as at 1, 2, 3, 19, Fig. 55. Drawing all the steps

this way will prevent a mistake that sometimes occurs, viz. the string-boards being cut too short. Cut the foot at the line AB, and the top, as at CD. This will give about one and a half inches more than the extreme length. Now cut out the treads and risers; the width of stair is, say, three feet, and we have one and a half inches on each side for string-boards. Allow three-eights of an inch for housing on each side. This will make the length of tread and risers two and one-fourth inches less than the full width of stairs; and as the treads must project their own thickness over rise, which is, say, one and a half inches, the full size of tread will be two feet by eleven and one-half inches, and of the risers two feet nine and three-fourths inches by six inches; and observe that the first riser will be the thickness of the tread less than the others; it will be only four and one-half inches wide. The reason of this riser being less than the others is because it has a tread thickness extra.

I will now leave the beginner to prepare all his work. Dress the risers on one face and one edge; dress the treads on one face and both edges, making them all of equal width; gauge the ends and the face edge to the required thickness, and round off the nosings; dress the string-boards to one face and edge to match each other.

A plan of a stair having 13 risers and three winders below is shown at Fig. 56. This shows how the whole stair may be laid out. It is inclosed between two walls.

The beginner in stair-work had better resort to the old method of using a story-rod for getting the number of risers. Take a rod and mark on it the exact height from top of lower floor to top of next floor, then

divide up and mark off the number of risers required. There is always one more riser than tread in every flight of stairs. The first riser must be cut the thickness of the tread less than the others.

When there are winders, special treatment will be

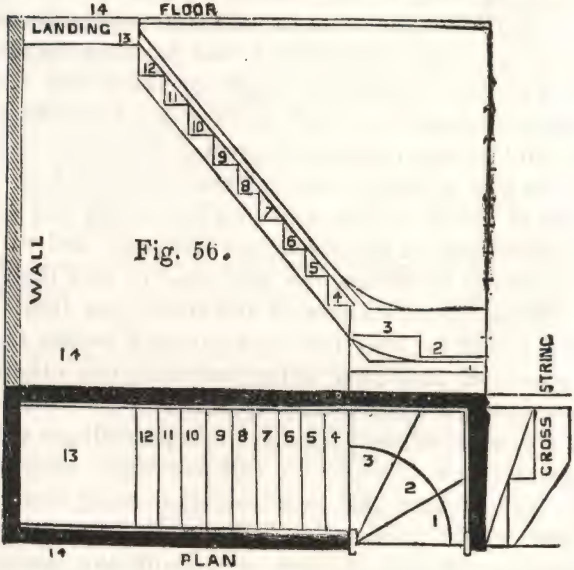


Fig. 56.

required, as shown in Fig. 56, for the treads, but the riser must always be the same width for each separate flight.

When the stair is straight and without winders, a rod may be used for laying off the steps. The width of the steps, or treads, will be governed somewhat by the space allotted for the run of the stairs.

There is a certain proportion existing between the tread and riser of a stair, that should be kept to as close as possible when laying out the work. Architects

say that the exact measurement for a tread and riser should be sixteen inches, or thereabouts. That is, if a riser is made six inches, the tread should be ten inches wide, and so on. I give a table herewith, showing the rule generally made use of by stair builders for determining the widths of risers and treads:

Treads Inches	*Risers* Inches	*Treads* Inches	*Risers* Inches
5	9	12	5½
6	8½	13	5
7	8	14	4½
8	7½	15	4
9	7	16	3½
10	6½	17	3
11	6	18	2½

It is seldom, however that the proportion of the

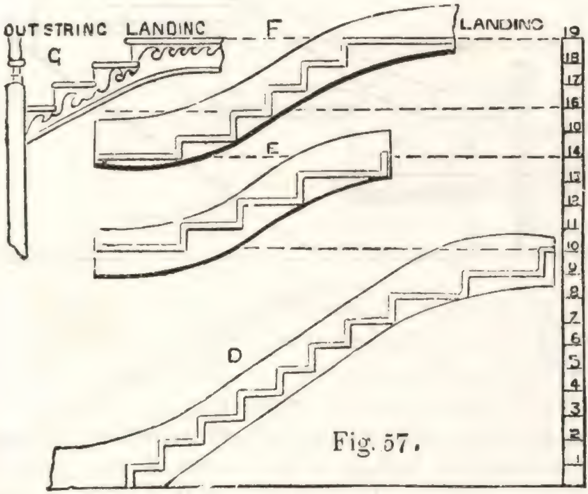


Fig. 57.

riser and step is exactly a matter of choice—the room

allotted to the stairs usually determines this proportion; but the above will be found a useful standard, to which it is desirable to approximate.

In better class buildings the number of steps is considered in the plan, which it is the business of the architect to arrange, and in such cases the height of the story-rod is simply divided to the number required.

An elevation of a stair with winders is shown at Fig. 57, where the story-rod is in evidence with the number of risers figured off.

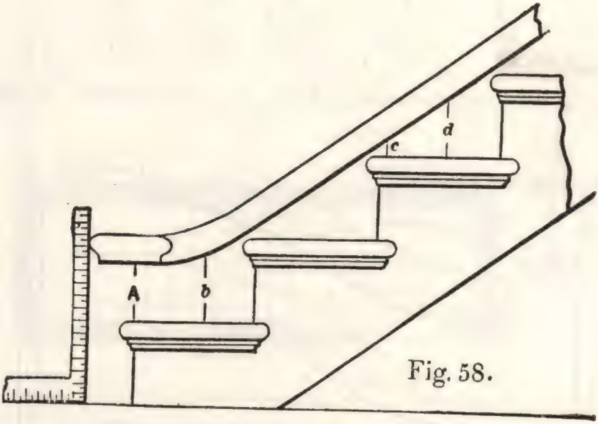


Fig. 58.

Fig. 58 shows a portion of an open string stair, with a part of the rail laid on it at AB, CD, and the newel cap with the projection at A. This shows how the cap should stand over the lower step.

Fig. 59 shows the manner of constructing the step; S represents the string, R the risers, T the tread, O the nosing and cove moulding, and B is a block glued or otherwise fastened to both riser and tread to render

them strong and firm. It will be seen the riser is let into the tread, and has a shoulder on the inside. The bottom of the riser is nailed to the back of the next lower tread, which binds the whole lower part together. The nosing of the stair is generally returned at the open end of the tread, and this covers the end wood of the tread and the joints of the balusters, as shown at Fig 60.

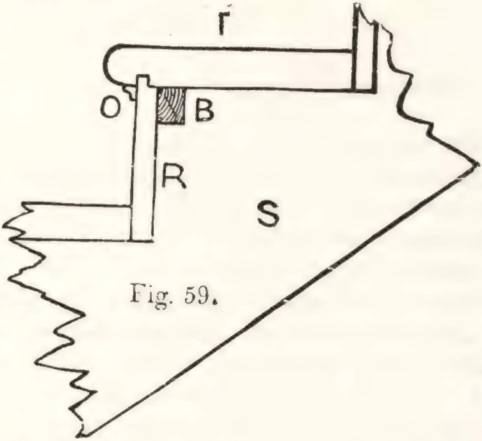


Fig. 59.

When a stair is bracketed, as shown at B, Fig 60, the point of the riser on its string end should be left standing past the string the thickness of the bracket, and the end of the bracket miters against it, thus avoiding the necessity of showing end wood or joint The cove should finish inside the length of the bracket, and the nosing should finish just outside the length of the bracket. When brackets are employed

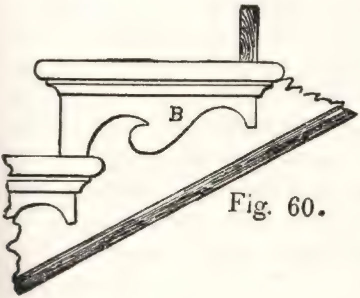


Fig. 60.

they should continue along the cylinder and all around the well hole trimmers, though they may be varied to suit conditions when continuously running on a straight horizontal facia.

CHAPTER III

JOINER'S WORK—USEFUL MISCELLANEOUS EXAMPLES

I am well aware that workmen are always on the lookout for details of work, and welcome everything in this line that is new. While styles and shapes change from year to year, like fashion in women's dress, the principles of construction never change, and styles of finish in woodwork that may be in vogue to-day, may be old-fashioned and discarded next year, therefore it may not be wise to load these pages with many examples of finish as made use of to-day. A few examples, however, may not be out of place, so I close this section by offering a few pages of such details as I feel assured will be found useful for a long time to come.

Fig. 1 is a full page illustration of three examples of stairs and newels in modern styles. The upper one is a colonial stairway with a square newel, as shown at A. A baluster is also shown, so that the whole may be copied if required. The second example shows two newels and balusters, and paneled string and spandril AB, also section of paneled work on end of short flight. The third shows a plain open stair, with baluster and newel, the latter starting from first step.

At Fig. 2, which is also a full page, seven of the latest designs for doors are shown. Those marked

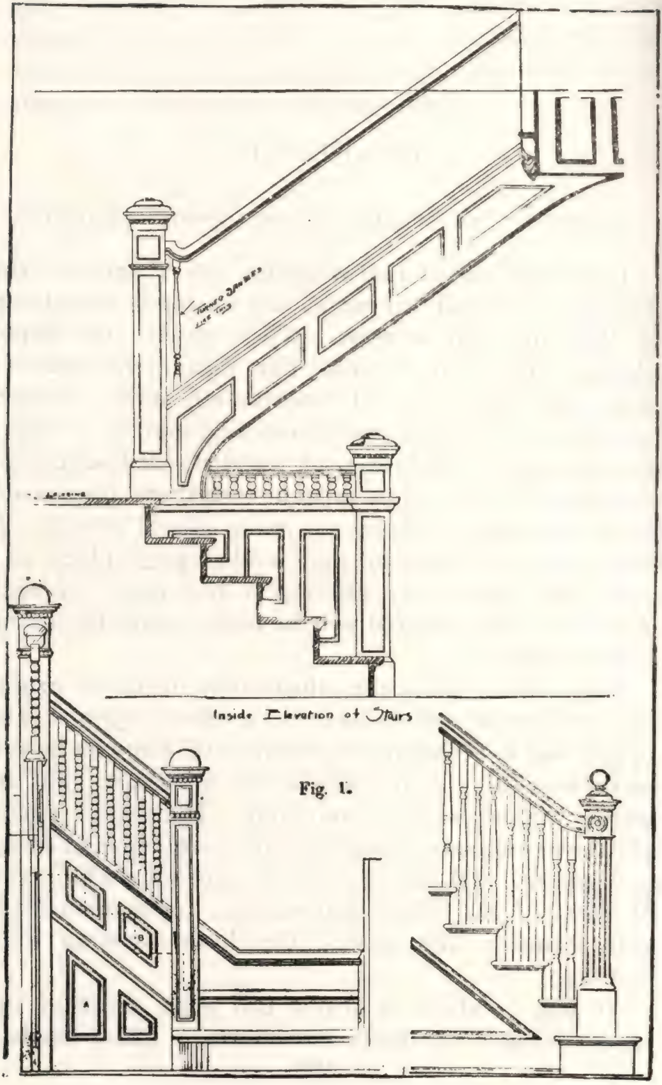
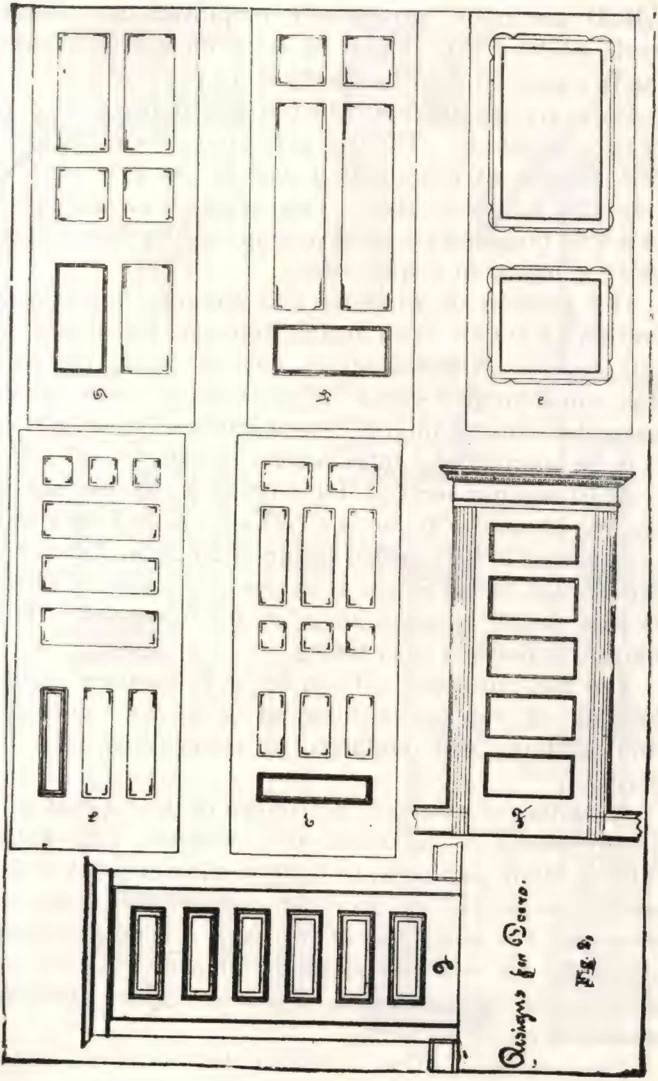


Fig. 1.



Designs for Doors.

Fig. 8.

ABCD are more particularly employed for inside work, while F and G may be used on outside work; the five-paneled door being the more popular.

There are ten different illustrations, shown at Fig. 3, of various details. The five upper ones show the general method of constructing and finishing a window frame for weighted sash. The section A shows a part of a wall intended for brick veneering, the upper story being shingled or clapboarded.

The position of windows and method of finishing bottom of frame, both inside and out, are shown in this section, also manner of cutting joists for sill. The same method—on a larger scale—is shown at C, only the latter is intended for a balloon frame, which is to be boarded and sided on the outside.

At B another method for cutting joists for sill is shown, where the frame is a balloon one. This frame is supposed to be boarded inside and out, and grounds are planted on for finish, as shown at the base. There is also shown a carpet strip, or quarter-round. The outside is finished with siding.

The two smaller sections show foundation walls, heights of stories, position of windows, cornices and gutters, and methods of connecting sills to joists.

A number of examples are shown in Fig. 4 that will prove useful. One is an oval window with keys. This is often employed to light vestibules, back stairs or narrow hallways. Another one, without keys, is shown on the lower part of the page. There are three examples of eyebrow dormers shown. These are different in style, and will, of course, require different construction.

The dormer window, shown at the foot of the page,

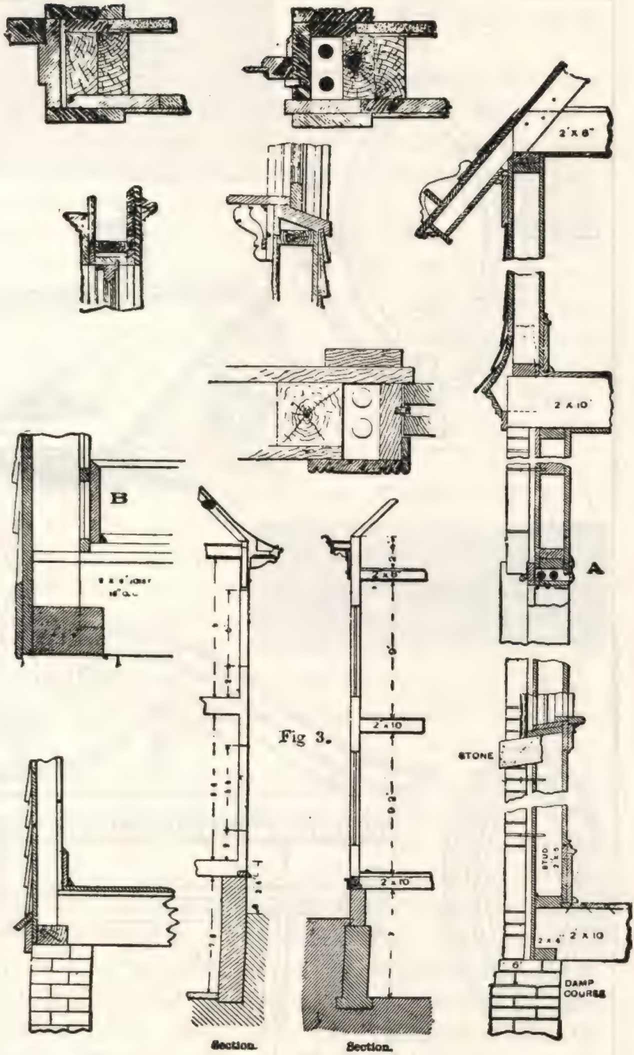

2" x 8"
2 x 10"
B
A
2 x 10
2 x 10
STONE
STUD
2 x 10
6"
DAMP COURSE
Section.
Section.

Fig 3.

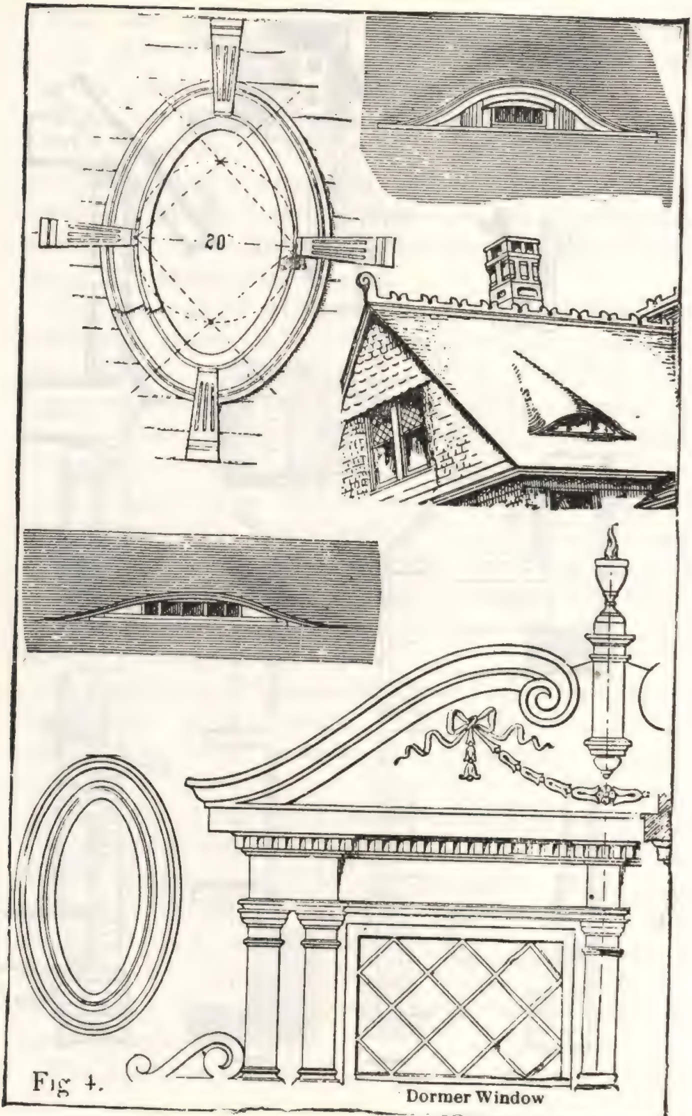


Fig 4.

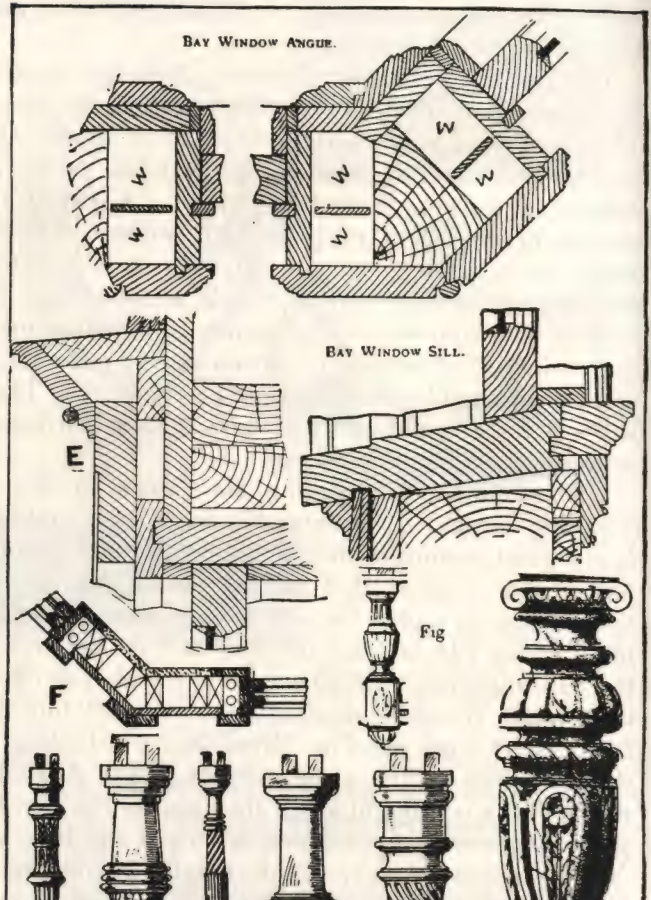
Dormer Window

is designed for a house built in colonial style, but may be adapted to other styles.

The four first examples in Fig. 5 show the sections of various parts of a bay window for a balloon frame. The manner of constructing the angle is shown, also the sill and head of window, the various parts and manner of working them being given. A part of the section of the top of the window is shown at E, the inside finish being purposely left off. At F is shown an angle of greater length, which is sometimes the case in bay windows. The manner of construction is quite simple. The lower portion of the page shows some fine examples of turned and carved work. These will often be found useful in giving ideas for turned work for a variety of purposes.

Six examples of shingling are shown in Fig. 6. The first sketch, A, is intended for a hip, and is a fairly good example, and if well done will insure a water-tight roof at that point. In laying out the shingles for this plan the courses are managed as follows: No. 1 is laid all the way out to the line of the hip, the edge of the shingle being planed off, so that course No. 2, on the adjacent side will line perfectly tight down upon it. Next No. 3 is laid and is dressed down in the same manner as the first, after which No. 4 is brought along the same as No. 2. The work proceeds in this manner, first right and then left.

In the second sketch, B, the shingles are laid on the hip in a way to bring the grain of the shingles more nearly parallel with the line of the hip. This method overcomes the projection of cross-grained points. Another method of shingling hips is shown at C and D. In putting on shingles by this method a line is snapped four inches from angle of hip on both sides


BAY WINDOW ANGUE.
W
BAY WINDOW SILL.
E
F
Fig

of the ridge, as indicated by the dotted lines in C, then bring the corner of the shingles of each course to the line as shown. When all through with the plain shingling, make a pattern to suit, and only cut the top to shape, as the bottoms or butts will break joints every time, and the hip line will lay square with the hip line, as shown at D; thus making a first-class water-tight job, and one on which the shingles will not curl up, and it will have a good appearance as well.

At E a method is shown for shingling a valley, where no tin or metal is employed. The manner of doing this work is as follows: First take a strip 4 inches wide and chamfer it on the edges on the outside, so that it will lay down smooth to the sheeting, and nail it into the valley. Take a shingle about 4 inches wide to start with and lay lengthwise of the valley, fitting the shingle on each side. The first course, which is always double, would then start with the narrow shingle, marked B, and carried up the valley, as shown in the sketch. Half way between each course lay a shingle, A, about 4 or 5 inches wide, as the case requires, chamfering underneath on each side, so that the next course will lie smooth over it.

If tin or zinc can be obtained, it is better it should be laid in the valley, whether this method be adopted or not.

The sketch shown at F is intended to illustrate the manner in which a valley should be laid with tin, zinc or galvanized iron. The dotted lines show the width of the metal, which should never be less than fourteen inches to insure a tight roof. The shingles should lap over as shown, and not less than four inches of the valley, H, should be clear of shingles

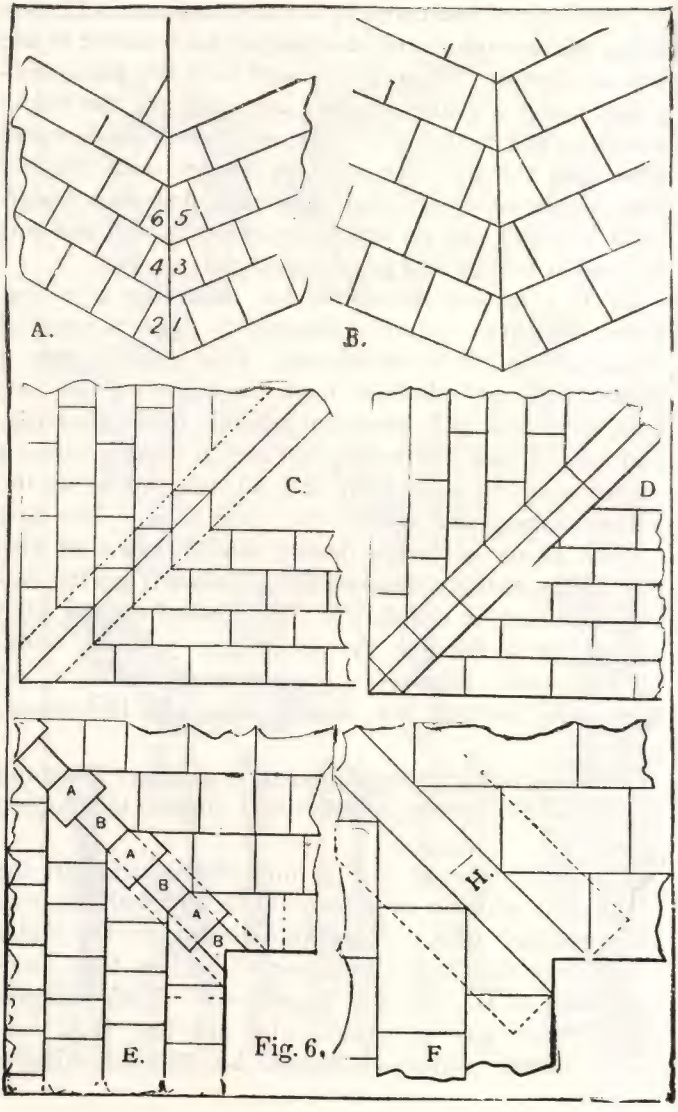


Fig. 6.

in order to insure plenty of space for the water to flow during a heavy rain storm. A great deal of care should be taken in shingling and finishing a valley, as it is always a weak spot in the roof.

PART IV

USEFUL TABLES AND MEMORANDA FOR BUILDERS

Table showing quantity of material in every four lineal feet of exterior wall in a balloon frame building, height of wall being given:

Length of Studs.	Size of Sills.	Size of Studs, Braces, etc.	Quantity of Rough Lumber	Quantity of Inch Boarding.	Siding in sup. feet	Tar Paper in sup. feet.
8	6x 6	2x4 studs.	42	36	40	74
10	6x 8	4x4 braces.	52	44	50	80
12	6x10	4x4 plates.	62	53	60	96
14	6x10	1x6 ribbons.	69	62	70	112
16	8x10		82	71	80	128
18	8x10	studs.	87	80	90	144
20	8x12	16 inches from	98	88	100	160
22	9x12	centers.	109	97	110	176
24	10x12		119	106	120	192
18	10x10	2x6 studs.	122	80	90	144
20	10x12	6x6 braces.	137	88	100	160
22	10x12	4x6 plates.	145	97	110	176
24	12x12	1x6 ribbons.	162	106	120	192
26	10x14		169	114	130	208
28	10x14	studs 16 inch centers.	176	123	140	224
30	12x14		198	132	150	240

Table showing amount of lumber in rafters, collar-piece and boarding, and number of shingles to four lineal feet of roof, measured from eave to eave over ridge. Rafters 16-inch centers:

Width of House, Feet.	Size of Rafters.	Size of Collar-piece.	Quantity of Lumber in Rafter and Collar-piece.	Quantity of Boarding, Feet.	No of Shingles.
14	2x4	2x4	39	61	560
16	2x4	2x4	45	70	640
18	2x4	2x4	50	79	720
20	2x4	2x4	56	88	800
22	2x4	2x4	62	97	880
24	2x4	2x4	67	106	960
20	2x6	2x6	84	88	800
22	2x6	2x6	92	97	880
24	2x6	2x6	101	106	960
26	2x6	2x6	109	115	1040
28	2x6	2x6	117	124	1120
30	2x6	2x6	126	133	1200

A proper allowance for waste is included in the above. Roof, one-fourth pitch.

Table showing the requisite sizes of girders and joists for warehouses, the span and distances apart being given:

Distance apart.	Span of Girders.				Joists.	Remarks.
	6 Feet	8 Feet.	10 Feet.	12 Feet.		
Feet.	Inches.	Inches.	Inches.	Inches.	Inches.	
10	8x12	12x13	12x16	14x18	2½x10	Girders to have a
12	9x12	12x14	12x18	16x18	3 x10	bearing at each
14	10x12	12x15	14x18	....	3 x12	end and joists 6 in.

Table as before, adapted for churches, public halls, etc.

Distance Apart.	Span of Girders.				Joists.	Remarks.
	6 Feet.	8 Feet.	10 Feet.	12 Feet.		
Feet.	Inches.	Inches.	Inches.	Inches.	Inches.	
12	6x10	8x12	12x14	12x16	2 x 8	
13	9x11	9x12	11x15	12x17	2 x 9	Bearings of
14	6x12	10x12	12x15	11x18	2 x 9	girders and
15	7x12	11x12	11x16	12x16	2 x 10	joists as
16	8x12	12x12	12x16	13x18	2 x 10	above.
17	8x12	9x14	12x17	14x18	2 x 12	
18	9x12	10x14	11x18	....	2 x 12	
19	9x12	11x14	12x18	....	$2\frac{1}{2}$ x 12	Both tables
20	10x12	12x14	13x18	....	$2\frac{1}{2}$ x 12	are calcu-
21	10x12	11x15	14x18	....	$2\frac{1}{2}$ x 12	lated for yel-
22	11x12	12x15	....	....	3 x 12	low pine.
23	11x12	11x16	....	....	3 x 12	
24	10x13	12x16	....	....	3 x 13	
25	10x13	12x17	....	....	3 x 13	
26	10x14	12x18	....	....	3 x 14	
27	10x14	12x18	....	....	3 x 14	

Table showing quantity of lumber in every four lineal feet of partition, studs being placed 16 centers, waste included:

Height of Partition, Feet.	Quantity of Studs 2x4 Feet.	If 2x6 Feet.
8	20	30
9	23	34
10	26	38
11	29	42
12	32	46
13	35	51
14	38	55
15	41	59
16	44	64

Lumber Measurement Table

Length.	2x4	Length.	2x6	Length.	2x8	Length.	2x10	Length.	3x6	Length.	3x8
12	8	12	12	12	16	12	20	12	18	12	24
14	9	14	14	14	19	14	23	14	21	14	28
16	11	16	16	16	21	16	27	16	24	16	32
18	12	18	18	18	24	18	30	18	27	18	36
20	13	20	20	20	27	20	33	20	30	20	40
22	15	22	22	22	29	22	37	22	33	22	44
24	16	24	24	24	32	24	40	24	36	24	48
26	17	26	26	26	35	26	43	26	39	26	52

3x10		3x12		4x4		4x6		4x8		6x6	
12	30	12	36	12	16	12	24	12	32	12	36
14	35	14	42	14	19	14	28	14	37	14	42
16	40	16	48	16	21	16	32	16	43	16	48
18	45	18	54	18	24	18	36	18	48	18	54
20	50	20	60	20	27	20	40	20	53	20	60
22	55	22	66	22	29	22	44	22	59	22	66
24	60	24	72	24	32	24	48	24	64	24	72
26	65	26	78	26	35	26	52	26	69	26	78

6x8		8x8		8x10		10x10		10x12		12x12	
12	48	12	64	12	80	12	100	12	120	12	144
14	56	14	75	14	93	14	117	14	140	14	168
16	64	16	85	16	107	16	133	16	160	16	192
18	72	18	96	18	120	18	150	18	180	18	216
20	80	20	107	20	133	20	167	20	200	20	240
22	88	22	117	22	147	22	183	22	220	22	264
24	96	24	128	24	160	24	200	24	240	24	288
26	104	26	139	26	173	26	217	26	260	26	312

Strength of Materials

Resistance to extension and compression, in pounds per square inch section of some materials.

Name of the Material.	Resistance to Extension.	Resistance to Compression	Tensile Stre th in Practice.	Comp. Strength in Practice.
White pine...	10,000	6,000	2,000	1,200
White oak....	15,000	7,500	3,000	1,500
Rock elm.....	16,000	8,011	3,200	1,602
Wroughtiron	60,000	50,000	12,000	10,000
Cast iron......	20,000	100,000	4,000	20,000

In practice, from one-fifth to one-sixth of the strength is all that should be depended upon

Table of Superficial or Flat Measure

By which the contents in *Superficial Feet*, of Boards, Plank, Paving, etc., of any *Length* and *Breadth*, can be obtained, by multiplying the decimal expressed in the table by the length of the board, etc.

Breadth inches.	Area of a lineal foot.	Breadth inches.	Area of a lineal foot.	Breadth inches.	Area of a lineal foot.	Breadth inches.	Area of a lineal foot.
¼	.0208	3¼	.2708	6¼	.5208	9¼	.7708
½	.0417	3½	.2916	6½	.5416	9½	.7917
¾	.0625	3¾	.3125	6¾	.5625	9¾	.8125
1	.0834	4	.3334	7	.5833	10	.8334
1¼	.1042	4¼	.3542	7¼	.6042	10¼	.8542
1½	.125	4½	.375	7½	.625	10½	.875
1¾	.1459	4¾	.3958	7¾	.6458	10¾	.8959
2	.1667	5	.4167	8	.6667	11	.9167
2¼	.1875	5¼	.4375	8¼	.6875	11¼	.9375
2½	.2084	5½	.4583	8½	.7084	11½	.9583
2¾	.2292	5¾	.4792	8¾	.7292	11¾	.9792
3	.25	6	.5	9	.75	12	1.0000

Round and Equal-Sided Timber Measure

Table for ascertaining the number of Cubical Feet, or solid contents, in a Stick of Round or Equal-Sided Timber, Tree, etc.

¼ girt in in.	Area in feet.	¼ girt in in.	Area in feet.	¼ girt in in.	Area in feet.	¼ girt in in.	Area in feet.	¼ girt in in.	Area in feet.
6	.25	10¾	.803	15½	1.668	20¼	2.898	25	4.34
6¼	.272	11	.84	15¾	1.722	20½	2.917	25¼	4.428
6½	.294	11¼	.878	16	1.777	20¾	2.99	25½	4.516
6¾	.317	11½	.918	16¼	1.833	21	3.062	25¾	4.605
7	.34	11¾	.959	16½	1.89	21¼	3.136	26	4.694
7¼	.364	12	1.	16¾	1.948	21½	3.209	26¼	4.785
7½	.39	12¼	1.042	17	2.006	21¾	3.285	26½	4.876
7¾	.417	12½	1.085	17¼	2.066	22	3.362	26¾	4.969
8	.444	12¾	1.129	17½	2.126	22¼	3.438	27	5.062
8¼	.472	13	1.174	17¾	2.187	22½	3.516	27¼	5.158
8½	.501	13¼	1.219	18	2.25	22¾	3.598	27½	5.252
8¾	.531	13½	1.265	18¼	2.313	23	3.673	27¾	5.348
9	.562	13¾	1.313	18½	2.376	23¼	3.754	28	5.444
9¼	.594	14	1.361	18¾	2.442	23½	3.835	28¼	5.542
9½	.626	14¼	1.41	19	2.506	23¾	3.917	28½	5.64
9¾	.659	14½	1.46	19¼	2.574	24	4.	28¾	5.74
10	.694	14¾	1.511	19½	2.64	24¼	4.084	29	5.84
10¼	.73	15	1.562	19¾	2.709	24½	4.168	29¼	5.941
10½	.766	15¼	1.615	20	2.777	24¾	4.254	29½	6.044

Shingling

To find the number of shingles required to cover 100 square feet deduct 3 inches from the length, divide the remainder by 3, the result will be the exposed length of a shingle; multiplying this with the average width of a shingle, the product will be the exposed area. Dividing 14,400, the number of square inches in a square, by the exposed area of a shingle will give the number required to cover 100 square feet of roof.

In estimating the number of shingles required, an allowance should always be made for waste.

Estimates on cost of shingle roofs are usually given per 1,000 shingles.

Table for Estimating Shingles

Length of Shingles.	Exposure to Weather, Inches.	No. of Sq. Ft. of Roof Covered by 1000 Shingles.		No of Shingles Required for 100 Sq. Ft. of Roof.	
		4 In. Wide.	6 In. Wide.	4 In. Wide.	6 In. Wide.
15 in.	4	111	167	900	600
18	5	139	208	720	480
21	6	167	250	600	400
24	7	194	291	514	343
27	8	222	333	450	300

Siding, Flooring, and Laths

One-fifth more siding and flooring is needed than the number of square feet of surface to be covered, because of the lap in the siding matching.

1,000 laths will cover 70 yards of surface, and 11 pounds of lath nails will nail them on. Eight bushels of good lime, 16 bushels of sand, and 1 bushel of hair, will make enough good mortar to plaster 100 square yards.

Excavations

Excavations are measured by the yard (27 cubic feet) and irregular depths or surfaces are generally averaged in practice.

Number of Nails Required in Carpentry Work

To case and hang one door, 1 pound.

To case and hang one window, ¾ pound.

Base, 100 lineal feet, 1 pound.

To put on rafters, joists, etc., 3 pounds to 1,000 feet.

To put up studding, same.

To lay a 6-inch pine floor, 15 pounds to 1,000 feet.

Sizes of Boxes for Different Measures

A box 24 inches long by 16 inches wide, and 28 inches deep will contain a barrel, or 3 bushels.

A box 24 inches long by 16 inches wide, and 14 inches deep will contain half a barrel.

A box 16 inches square and 8⅖ inches deep, will contain 1 bushel.

A box 16 inches by 8⅖ inches wide and 8 inches deep, will contain half a bushel.

A box 8 inches by 8⅖ inches square and 8 inches deep, will contain 1 peck.

A box 8 inches by 8 inches square and 4⅕ inches deep, will contain 1 gallon.

A box 8 inches by 4 inches square and 4⅘ inches deep, will contain half a gallon.

A box 4 inches by 4 inches square and 4⅕ inches deep, will contain 1 quart.

A box 4 feet long, 3 feet 5 inches wide, and 2 feet 8 inches deep, will contain 1 ton of coal.

Masonry

Stone masonry is measured by two systems, quarryman's and mason's measurements.

By the quarryman's measurements the actual contents are measured—that is, all openings are taken out and all corners are measured single.

By the mason's measurements, corners and piers are doubled, and no allowance made for openings less than 3′ 0″x5′ 0″ and only half the amount of openings larger than 3′ 0″x5′ 0″.

Range work and cut work is measured superficially and in addition to wall measurement.

An average of six bushels of sand and cement per perch of rubble masonry.

Stone walls are measured by the perch (24¾ cubic feet, or by the cord of 128 feet). Openings less than 3 feet wide are counted solid; over 3 feet deducted, but 18 inches are added to the running measure for each jamb built.

Arches are counted solid from their spring. Corners of buildings are measured twice. Pillars less than 3 feet are counted on 3 sides as lineal, multiplied by fourth side and depth.

It is customary to measure all foundation and dimension stone by the cubic foot. Water tables and base courses by lineal feet. All sills and lintels or ashlar by superficial feet, and no wall less than 18 inches thick.

The height of brick or stone piers should not exceed 12 times their thickness at the base.

Masonry is usually measured by the perch (containing 24.75 cubic feet), but in practice 25 cubic feet are considered a perch of masonry.

Concreting is usually measured by the cubic yard (27 cubic feet).

A cord of stone, 3 bushels of lime and a cubic yard of sand, will lay 100 cubic feet of wall.

Cement, 1 bushel, and sand, 2 bushels, will cover 3½ square yards 1 inch thick, 4½ square yards ¾ inch thick, and 6¾ square yards ½ inch thick; 1 bushel of cement and 1 of sand will cover 2¼ square yards 1 inch thick, 3 square yards ¾ inch thick and 4½ square yards ½ inch thick.

Brick Work

Brick work is generally measured by 1,000 bricks laid in the wall. In consequence of variations in size of bricks, no rule for volume of laid brick can be exact. The following scale is, however, a fair average:

7	com.	bricks	to a	super.	ft.	4	in.	wall.
14	"	"	"	"	"	9	"	"
21	"	"	"	"	"	13	"	"
28	"	"	"	"	"	18	"	"
35	"	"	"	"	"	22	"	"

Corners are not measured twice, as in stone work. Openings over 2 feet square are deducted. Arches are counted from the spring. Fancy work counted 1½ bricks for 1. Pillars are measured on their face only.

A cubic yard of mortar requires 1 cubic yard of sand and 9 bushels of lime, and will fill 30 hods.

One thousand bricks closely stacked occupy about 56 cubic feet.

One thousand old bricks, cleaned and loosely stacked, occupy about 72 cubic feet.

One superficial foot of gauged arches requires 10 bricks.

Pavements, according to size of bricks, take 38 brick on flat and 60 brick on edge per square yard, on an average.

Five courses of brick will lay 1 foot in height on a chimney, 6 bricks in a course will make a flue 4 inches wide and 12 inches long, and 8 bricks in a course will make a flue 8 inches wide and 16 inches long.

Slating

A square of slate or slating is 100 superficial feet.

In measuring, the width of eaves is allowed at the widest part. Hips, valleys and cuttings are to be measured lineal, and 6 inches extra is allowed.

The thickness of slates required is from $\frac{3}{16}$ to $\frac{5}{16}$ of an inch, and their weight varies when lapped from $\frac{4}{8}$ to 6¾ pounds per square foot.

The "laps" of slates vary from 2 to 4 inches, the standard assumed to be 3 inches.

To Compute the Number of Slates of a Given Size Required per Square

Subtract 3 inches from the length of the slate, multiply the remainder by the width and divide by 2. Divide 14,400 by the number so found and the result will be the number of slates required.

Table showing number of slates and pounds of nails required to cover 100 square feet of roof.

Sizes of Slate	Length of Exposure.	No. Required.	Nails Required.
14 in. x 28 in.	12½ in.	83	.6 lbs.
12 x 24	10½	114	.833
11 x 22	9½	138	1.
10 x 20	8½	165	1.33
9 x 18	7½	214	1 5
8 x 16	6½	277	2.
7 x 14	5½	377	2.66
6 x 12	4½	533	3.8

Approximate Weight of Materials for Roofs

Material.	Average Weight, Lb. per Sq. Ft.
Corrugated galvanized iron, No. 20, unboarded	2¼
Copper, 16 oz. standing seam	1¼
Felt and asphalt, without sheathing	2
Glass, ⅛ in. thick	1¾
Hemlock sheathing, 1 in. thick	2
Lead, about ⅛ in. thick	6 to 8
Lath-and-plaster ceiling (ordinary)	6 to 8
Mackite, 1 in. thick, with plaster	10
Neponset roofing felt, 2 layers	⅛
Spruce sheathing, 1 in. thick	2½
Slate, $\frac{3}{16}$ in. thick, 3 in. double lap	6¾
Slate, ⅛ in. thick, 3 in. double lap	4½
Shingles, 6 in. x 18 in., ⅓ to weather	2
Skylight of glass, $\frac{3}{16}$ to ½ in., including frame	4 to 10
Slag roof, 4-ply	4
Terne Plate, IC, without sheathing	½
Terne Plate, IX, without sheathing	⅝
Tiles (plain), 10½ in. x 6¼ x ⅝ in.—5¼ in. to weather	18
Tiles (Spanish) 14½ in. x 10½ in. 7¼ in. to weather	8½
White-pine sheathing, 1 in. thick	2½
Yellow-pine sheathing, 1 in. thick	4

Snow and Wind Loads

Data in regard to snow and wind loads are necessary in connection with the design of roof trusses.

Snow Load.—When the slope of a roof is over 12 inches rise per foot of horizontal run, a snow and accidental load of 8 pounds per square foot is ample. When the slope is under 12 inches rise per foot of run, a snow and accidental load of 12 pounds per square foot should be used. The snow load acts vertically, and therefore should be added to the dead load in designing roof trusses. The snow load may be neglected when a high wind pressure has been considered, as a great wind storm would very likely remove all the snow from the roof.

Wind Load.—The wind is considered as blowing in a horizontal direction, but the resulting pressure upon the roof is always taken normal (at right angles) to the slope. The wind pressure against a vertical plane depends on the velocity of the wind, and, as ascertained by the United States Signal Service at Mount Washington, N. H., is as follows:

Velocity. (Mi. per Hr.)	*Pressure.* (Lb. per Sq. Ft.)	
10	0.4	Fresh breeze.
20	1.6	Stiff breeze.
30	3.6	Strong wind.
40	6.4	High wind.
50	10.0	Storm.
60	14.4	Violent storm.
80	25.6	Hurricane.
100	40.0	Violent hurricane.

The wind pressure upon a cylindrical surface is one-half that upon a flat surface of the same height and width.

Since the wind is considered as traveling in a horizontal direction, it is evident that the more nearly vertical the slope of the roof, the greater will be the pressure, and the more nearly horizontal the slope, the less will be the pressure. The following table gives the pressure exerted upon roofs of different slopes, by a wind pressure of 40 pounds per square foot on a vertical plane, which is equivalent in intensity to a violent hurricane.

UNITED STATES WEIGHTS AND MEASURES

Land Measure

1 sq. acre = 10 sq. chains = 100,000 sq. links = 6,272,640 sq. in.
1 " " = 160 sq. rods = 4,840 sq. yds. = 43,560 sq. ft.

Note.—208.7103 feet square, or 69.5701 yards square, or 220 feet by 198 feet square=1 acre.

Cubic or Solid Measure

1 cubic yard = 27 cubic feet.
1 cubic foot = 1,728 cubic inches.
1 cubic foot = 2,200 cylindrical inches.
1 cubic foot = 3,300 spherical inches.
1 cubic foot = 6,600 conical inches.

Linear Measure

12	inches (in.)	= 1 foot	ft.
3	feet	= 1 yard	yd.
5½	yards	= 1 rod	rd.
40	rods	= 1 furlong	fur
8	furlongs	= 1 mile	mi.

in.	ft.	yd.	rd.	fur.	mi.
36 =	3 =	1			
198 =	16.5 =	5.5 =	1		
7,920 =	660 =	220 =	40 =	1	
63,360 =	5,280 =	1,760 =	320 =	8 =	1

Square Measure

144	square inches (sq. in.)	= 1 square foot	sq. ft.
9	square feet	= 1 square yard	sq. yd.
30¼	square yards	= 1 square rod	sq. rd.
160	square rods	= 1 acre	A.
640	acres	= 1 square mile	sq. mi.

Sq. mi.	A.	Sq. rd.	Sq. yd.	Sq. ft.	Sq. in.
1 =	640 =	102,400 =	3,097,600 =	27,878,400 =	4,014,489,600

Miscellaneous Measures and Weights

1 perch of stone = 1 ft. × 1 ft. 6 in. × 16 ft. 6 in. = 24.75 ft. cubic.
1 cord of wood, clay, etc., = 4 ft. × 4 ft. × 8 ft. = 128 ft. cubic.
1 chaldron = 36 bushels or 57.25 ft. cubic.
1 cubic foot of sand, solid, weighs 112½ lbs.
1 cubic foot of sand, loose, weighs 95 lbs.
1 cubic foot of earth, loose, weighs 93¾ lbs.
1 cubic foot of common soil weighs 124 lbs.
1 cubic foot of strong soil weighs 127 lbs.
1 cubic foot of clay weighs 120 to 135 lbs.
1 cubic foot of clay and stone weighs 160 lbs.
1 cubic foot of common stone weighs 160 lbs.
1 cubic foot of brick weighs 95 to 120 lbs.
1 cubic foot of granite weighs 169 to 180 lbs.
1 cubic foot of marble weighs 166 to 170 lbs.
1 cubic yard of sand weighs 3,037 lbs.
1 cubic yard of common soil weighs 3,429 lbs.

Safe Bearing Loads

Brick and Stone Masonry.	Lb. per Sq. In.
Brick Work.	
Bricks, hard, laid in lime mortar	100
Hard, laid in Portland cement mortar	200
Hard, laid in Rosendale cement mortar	150
Masonry.	
Granite, capstone	700
Squared stonework	350
Sandstone, capstone	350
Squared stonework	175
Rubble stonework, laid in lime mortar	80
Rubble stonework, laid in cement mortar	150
Limestone, capstone	500
Squared stonework	250
Rubble, laid in lime mortar	80
Rubble, laid in cement mortar	150
Concrete, 1 Portland, 2 sand, 5 broken stone	150

Foundation Soils.	Tons per Sq. Ft.
Rock, hardest in native bed	100 —
Equal to best ashlar masonry	25-40
Equal to best brick	15-20
Clay, dry, in thick beds	4- 6
Moderately dry, in thick beds	2 4
Soft	1- 2
Gravel and course sand, well cemented	8-10
Sand, compact and well cemented	4- 6
Clean, dry	2- 4
Quicksand, alluvial soil, etc.	.5- 1

Capacity of Cisterns for Each 10 Inches in Depth

Twenty-five feet in diameter holds	3059 gallons
Twenty feet in diameter holds	1958 gallons
Fifteen feet in diameter holds	1101 gallons
Fourteen feet in diameter holds	959 gallons
Thirteen feet in diameter holds	827 gallons
Twelve feet in diameter holds	705 gallons
Eleven feet in diameter holds	592 gallons
Ten feet in diameter holds	489 gallons
Nine feet in diameter holds	396 gallons
Eight feet in diameter holds	313 gallons
Seven feet in diameter holds	239 gallons
Six and one-half feet in diameter holds	206 gallons
Six feet in diameter holds	176 gallons
Five feet in diameter holds	122 gallons
Four and one-half feet in diameter holds	99 gallons

Four feet in diameter holds.. 78 gallons
Three feet in diameter holds.. 44 gallons
Two and one-half feet in diameter holds.................... 30 gallons
Two feet in diameter holds.. 19 gallons

Number of Nails and Tacks per Pound

NAILS.

Name.		Size.		No. per lb.	
3	penny. fine	1⅛	inch	760	nails
3	"	.......1¼	"	480	"
4	"	.......1½	"	300	"
5	"	.......1¾	"	200	"
6	"	.......2⅛	"	160	"
7	"	.......2¼	"	128	"
8	"	.......2½	"	92	"
9	"	.......2¾	"	72	"
10	"	3	"	60	"
12	"	.......3¼	"	44	"
16	"	.......3½	"	32	"
20	"	4	"	24	"
30	"	.......4¼	"	18	"
40	"	5	"	14	"
50	"	.......5½	"	12	"
6	" fence	2	"	80	"
8	" "	2½	"	50	"
10	" "	3	"	34	"
12	" "	3¼	"	29	"

TACKS.

Name.		Length.		No. per lb.
1	oz.	.......⅛	inch	16,000
1½	"	3-16	"	10,666
2	"	.......¼	"	 8,000
2½	"	5-16	"	 6,400
3	"	.......⅜	"	 5,333
4	"	7-16	"	 4,000
6	"	9-16	"	 2,666
8	"	.......⅝	"	 2,000
10	"	11-16	"	 1,600
12	"	.......¾	"	 1,333
14	"	13-16	"	 1,143
16	"	.......⅞	"	 1,000
18	"	15-16	"	 888
20	"	1	"	 800
22	"	.......1 1-16	"	 727
24	"	.......1⅛	"	 660

Wind Pressures on Roofs

(Pounds per Square Foot.)

Rise, Inches per Foot of Run.	Angle with Horizontal.	Pitch, Proportion of Rise to Span	Wind Pressure, Normal to Slope.
4	18° 25′	$\frac{1}{6}$	16.8
6	26° 33′	$\frac{1}{4}$	23.7
8	33° 41′	$\frac{1}{3}$	29.1
12	45° 0′	$\frac{1}{2}$	36.1
16	53° 7′	$\frac{2}{3}$	38.7
18	56° 20′	$\frac{3}{4}$	39.3
24	63° 27′	1	40.0

In addition to wind and snow loads upon roofs, the weight of the principals or roof trusses, including the other features of the construction, should be figured in the estimate. For light roofs, having a span of not over 50 feet, and not required to support any ceiling the weight of the steel construction may be taken at 5 pounds per square foot; for greater spans, 1 pound per square foot should be added for each 10 feet increase in the span.

SUPPLEMENT TO

MODERN CARPENTRY AND JOINERY.

The aim in preparing this has been to supply necessary information for enabling a practical joiner to become a competent airtight-case maker, without the tedium of waiting, perhaps for years, until chance brings him into contact with one who has made a specialty of this class of work. I have endeavored, by means of illustrations, to elucidate as clearly as possible the points which are so frequently the cause of failure to those who, while having a good knowledge of wood-working, have not had the advantages of direct practical tuition in the intricacies of airtight-case making.

Before proceeding with the explanations, I would point out that the first and most important rule in joinery is to have the stuff planed up true, and gauged accurately to size.

I. AIRTIGHT WALL CASE WITH GLASS OR WOOD ENDS.

The general drawings of the airtight wall-case with glazed ends are given in Figs. 1 to 5 and the details in Figs. 6 to 9.

Framework. Figs. 6 and 7 give the width of the top and bottom rails for the front frame of the case, and, by adding the width of the top and bottom door-rails to each we determine the width of the rails required for the ends of the case, as shown in Fig. 5. The angle-stile must be ¼ inch more in thickness than the thick-

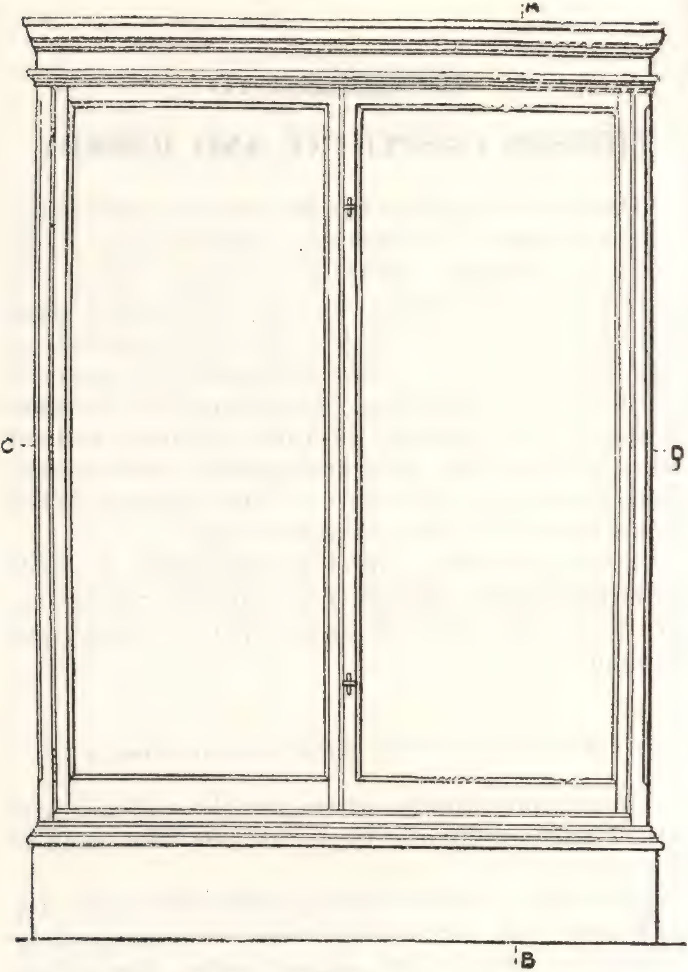


Fig. 1.

ness of the doors, in order to allow of a rebate being formed to receive the glass at the ends of the case. (See M Fig. 8.)

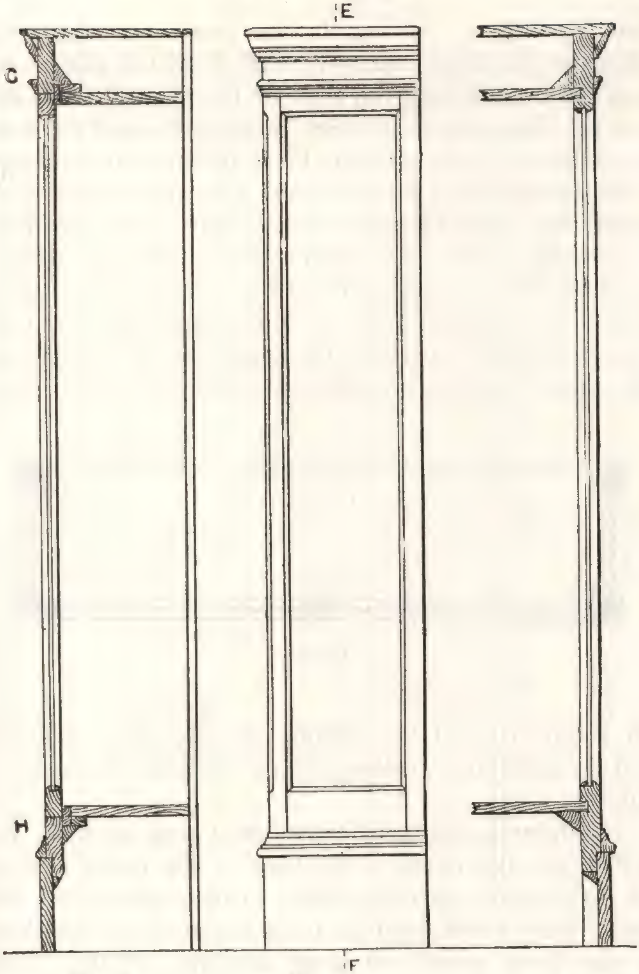


Fig. 2. Fig. 4. Fig. 5.

In setting out the framework (which is mortised and tenoned together in the ordinary way) the face shoulders of the front rails should be ⅛ inch longer than the

back shoulders. An eighth inch bead—for which the allowance has been made—is worked on the angle-stiles and bottom rail only, the edge of the top rail being left square. The moulding which is planted round the case, as shown in Fig. 6, serves to break the joint of the doors. The shoulders on the end rails are square with each other, the rebate being the same depth as the moulding.

Airtight joints. To make successfully the airtight joint between the angle-stile of the case and the hanging stile of the door (see Fig. 8) three planes are required. The first plane is used on the angle-stile for forming at the same time the two grooves, each 3/16 inch wide;

Fig. 3.

the second is used for working the two fillets together and the third for working the two hollows in the door stiles.

The front part of the frame must now be fitted together and the joints at the back of the frame cleared off, to allow the airtight planes to be worked from the back of the frame, that is, from the inside of the case, as the doors would not close accurately if they were worked from the face or outside.

After the front frame has been fitted together as described, it must be taken apart, and the angle-stiles worked with plane No. 1 When this has been done,

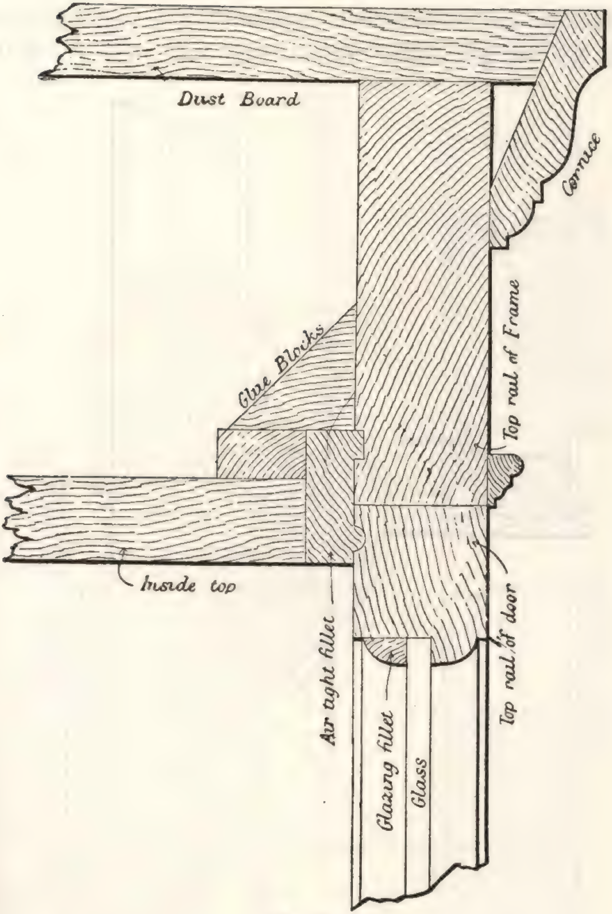


Fig. 6.

the fillets must be glued in the grooves, and, when set, rounded over with plane No. 2. The fillets will not require to be taken to the exact width before rounding over, as plane No. 2 works all surplus stuff away.

For the joint between the top and bottom rails of doors and the airtight fillets respectively, two planes are re-

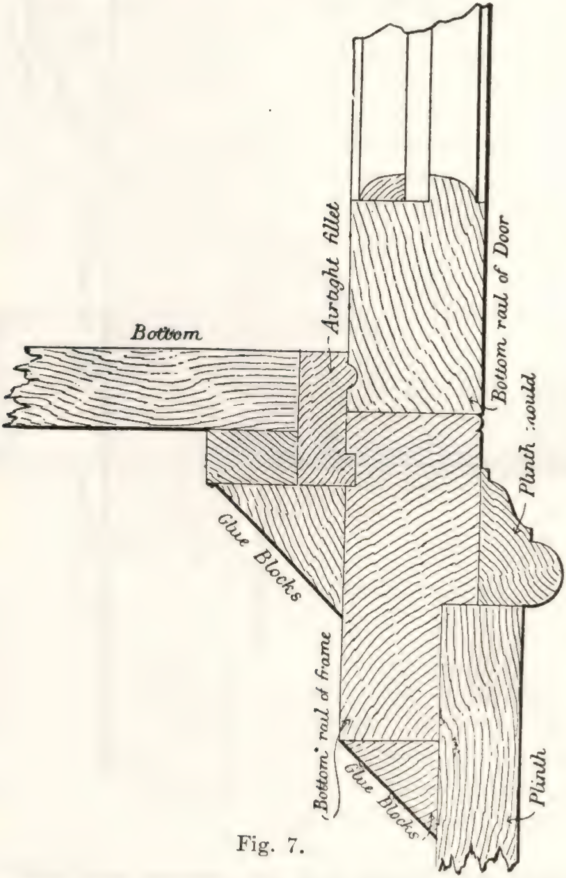


Fig. 7.

quired; the first for sticking the airtight fillet, and the second for working the small hollow on the door rails to match the fillet.

Continuing with the framework. After rounding the fillets in the angle-stiles, groove the top and bottom

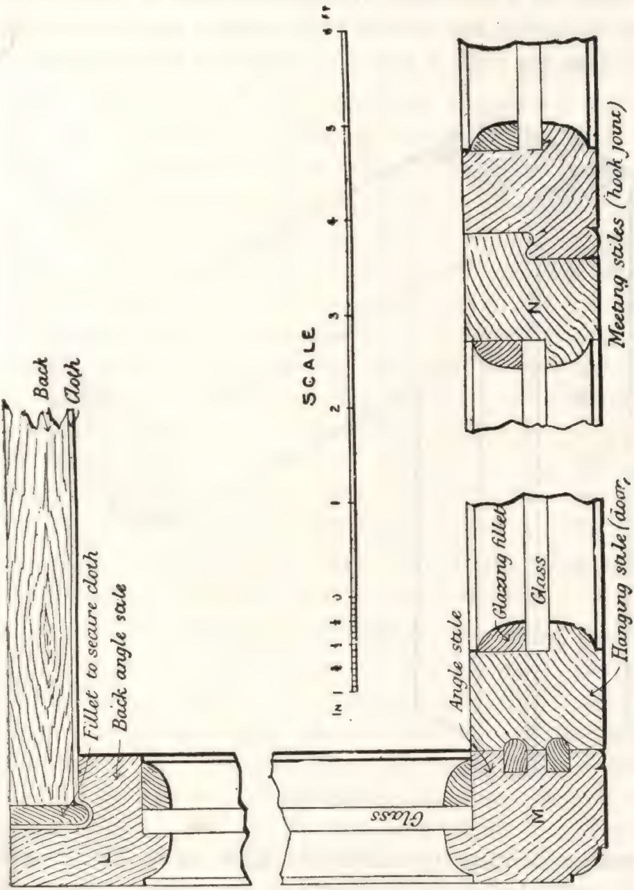


Fig. 8.

rails to receive the tongue on the airtight fillets as shown in Figs. 6 and 7 and rebate the bottom rails to rest on the plinth, Fig. 7. The top and bottom rails at each end

of the case are trenched to receive respectively the ends of the inside top and inside bottom, Fig. 5. Care must be taken to make these trenches in such a way as to keep the inside top and the inside bottom in the positions shown in the Figs. 6 and 7. Rebate the back angle-stile

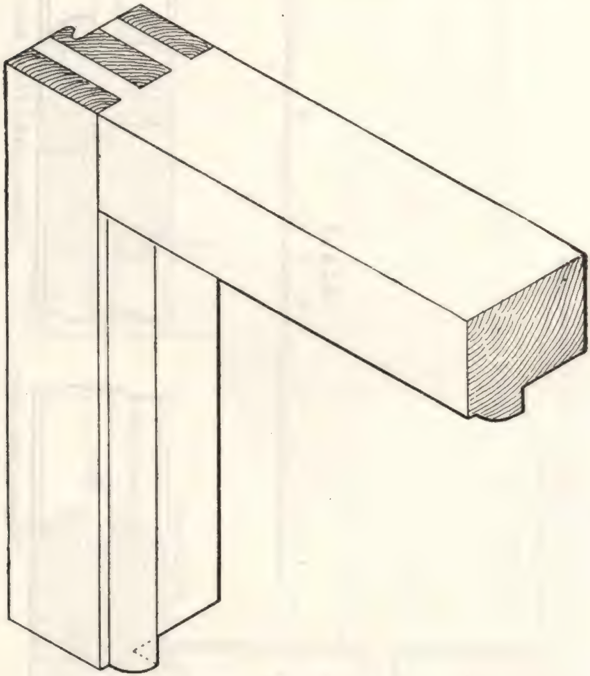


Fig. 9.

of each end frame to receive the back, as in Fig. 8, and run a small hollow in the angle of the rebate. Glue and pin the airtight fillet on the front edges of the inside top and bottom respectively; also glue the fillet on the back of each in order to strengthen the airtight fillet, and

make out the thickness to receive the glue-blocks as shown. An ovolo or other moulding is now worked on the external angles of the two front angle-stiles as shown in Fig. 8, the moulding being stopped in a line with the top and bottom rails respectively of the doors, Fig. 1.

The body of the case must now be put together, care being taken to glue-block the front frame and ends securely to the bottom and top, as well as behind the plinth, which is screwed to the bottom rails from the back.

Match-boards are used for the back, the boards being run to the floor, as shown in Fig. 2. Mitre the cornice round the front and ends, screwing it from the back of the top rails; cut the dust-board to fit on the top edges of the rails and bevel against the cornice; having previously rebated it to receive the back of the case. Before the back is fastened, the cloth, Fig. 8, should be placed in the rebate of the stile, the fillet placed on top of the cloth and pressed into the hollow, and then fastened to the stile with screws, the cloth thus being securely held between the fillet and the stile. The cloth can now be stretched taut and fixed at the other end in the same way, and the boards fastened in.

Doors. In planing up the stuff for the doors, the same gauge must be used as that for the frame of the case. When setting out for the doors, take the width and height accurately, and allow 1/16 inch on the height for fitting in. The width is set out as for ordinary folding doors, viz.: allowing half the hook-joint on each door, and ⅛ inch for jointing and fitting in. The best way to allow for fitting is to have each stile 1/16 inch greater in width than the finished size required.

The rails abutting against each angle-stile are single-mortised and tenoned together as in ordinary work,

but double mortises and tenons must be used at the top and bottom of each meeting stile, as shown in Fig. 9. The reason for using the double tenon is, that if a single tenon were used, the ends of the tenon would slip off after the hook-joint had been made.

Presuming the doors to be wedged up, level off the joints at the shoulders, when the doors will be ready for jointing together and fitting to the case.

Hook-Joint. The following is the best method of making a well fitting joint. First rebate the stiles (the rebate being 1/8 inch less in width than the thickness of the doors, and 5/16 inch deep), and next bevel the edges of the doors, bringing the rebate to a depth of 1/4 inch, Fig. 8. The doors must now be worked with a hollow and round on the edge of the rebate to form the hook-joint. For this purpose a hook-joint plane is required. There is an adjustable depth-gauge on the side of the plane, which can be easily set for working different thicknesses of stuff. Before working the doors with the plane, it is advisable to work a piece of stuff of the same thickness as the doors. Cut the piece thus worked into two, and put the joint together. This will test the accuracy of the setting of the plane. If the faces do not come flush with each other, the gauge on the plane must be raised or lowered accordingly.

Having fitted the meeting stiles, place the doors together across the bench, as they can thus be more easily taken to the exact width and height of the frame of the case. After the doors have been fitted in the opening, work with the airtight planes as previously instructed, always remembering to hold the fence of plane No. 3 on the back side of the door while forming the hollows on the hanging stiles. With plane No. 2 the small hollow

on the top and bottom rails to match the airtight fillet is worked.

After working the doors as described, clean off the back side, place the doors in position, and clean off the face to the level of the frame. Take the doors out and

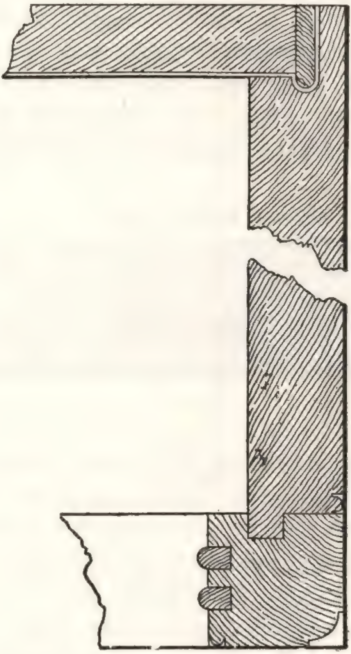


Fig. 10.

work the bead on the joint between the doors, Fig. 8. This bead is flatter than usual and has a very small quirk.

The doors are hung to the frame, each by three hinges. The top and bottom hinges are usually kept their own

depth from the top and bottom edges of the doors respectively, e. g., a 2½ inch hinge will be 2½ inches from the edge. The handles on the meeting stiles are respectively about 9 inches from the upper and lower edges of door.

All glass in the doors must be carefully packed with small slips of wood between the edges of the glass and the frame of the door, in order to keep the frame rigid. The woodwork being so slight, the doors would sag when hung if the glass were not packed tightly, as all the weight of the glass would fall on the bottom rail.

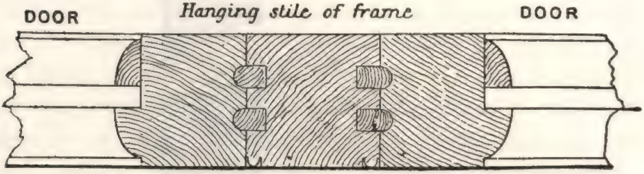


Fig. 11.

Shelves. The following is the best method to adopt for fitting the case with shelves, as, when fitted in this way, the shelves can be moved to any required height. To the back of the case screw two pieces of iron, one at each side, extending from the top to the bottom of the case. These must previously have been drilled and tapped their whole length, the space between each hole being ½ inch from centre to centre, and each hole being large enough to receive a 3/16 inch screw. A malleable-iron bracket about 3 inches long on the back edge—the length of the top edge being the width of the shelf—is now required, having a small piece projecting above the top edge in which is drilled a plain hole, and having a pin near the bottom edge. The pin at the bottom edge

is placed in one of the holes in the tapped bar, and a 3/16 inch screw is passed through the hole at the top edge and screwed into the bar, thus securing the bracket firmly. Care must be taken to have the same distance between the centres of any two holes in the bar.

Fig. 10 shows a horizontal section through a showcase having solid ends.

Fig. 11 shows a horizontal section through the centre hanging stile in the front frame of a wide showcase, when two pairs of doors are required. It is worked in the same manner as previously described for hanging stiles.

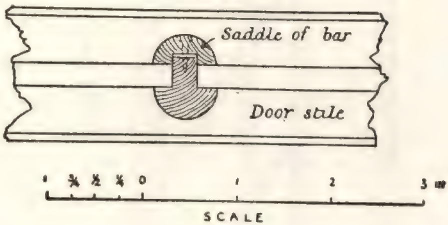


Fig. 12.

Fig. 12 shows a section of a cross bar in doors. This is only required where sheet glass is used. Each end of the bar is sunk into the moulding of the door-stiles. The saddle is cut between the rebates, and secured to the bar.

Plinths separate from the case. If the showcase is over 6 feet 6 inches in height, or the plinth is of a greater depth than 12 inches, it is advisable to make the plinth separate from the case. Instead of the bottom rail being rebated behind the plinth, as shown in Fig. 7, a frame must be made out of 1½ inch by 3 inch stuff dovetailed together at the angles; and two or three bearers should

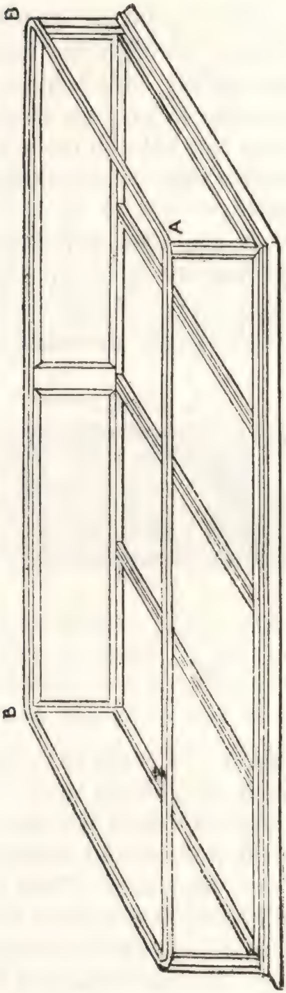


Fig. 13.

be mortised and tenoned between the front and back rails (as the length of the case may require). At each angle, and under each end of the bearers, a leg is stump-

tenoned into the under side of the rails to support the case. When this is done, the plinth should be mitred round the frame. It should be screwed from the back, and glue-blocks used in all the angles.

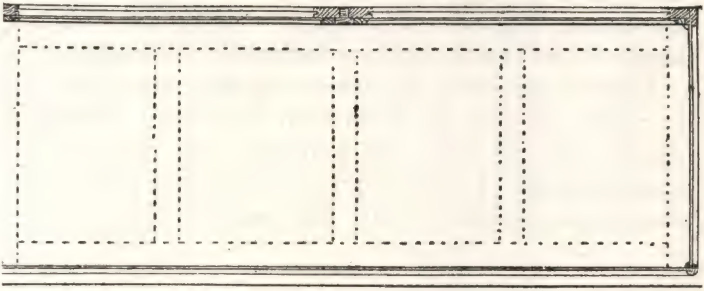


Fig. 14.

An isometrical projection of a counter-case is shown in Fig. 3. The top, sides, and front are of plate-glass. Mirrors are placed on the inside of the doors at the back of the case. The divisions on the bottom show the position of the trays.

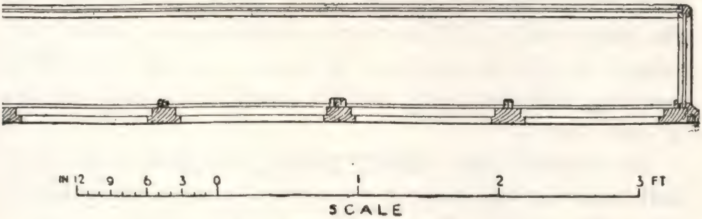


Fig. 15.

Before commencing work, it is absolutely necessary to draw Figs. 14 and 15 full size, to enable the taking off and working to an exact size of the various parts required to be done.

Bottom of case. Commence with the frame, which should be made out of well-seasoned pine. The width of the bottom frame will be the extreme width of the case less the thickness of the moulding on the front edge and 1½ inch for a hardwood slip on the back edge of the frame, Fig. 17. The length will be the extreme length of the case *minus* two thicknesses of moulding.

Mortise and tenon the frame together, and rebatc it to receive ⅝ inch panels flush on the inside; then glue up and take to size. The hardwood slip can now be jointed and glued on, a tongued and grooved joint being used for the purpose. After this has been done, the air-

Fig. 16.

tight rebate to receive the doors should be worked on the hardwood slip. In order to make a good job of the rebate, it will be necessary to have a special plane for working both the rebate and the small half-round tongue at one time.

To complete the bottom, groove the front edge and both ends for the tongue, then mitre and fix the moulding to the frame. The moulding must be specially noted. It must project above the bottom 3/16 inch to form a rebate for the glass; and the first member, i. e. the part projecting, must be rounded to intersect with the upright angle-bars, Figs. 17 and 18, with mitre into the mouldings.

The panels in the bottom are to be screwed to the frame. Before putting the whole case together, they

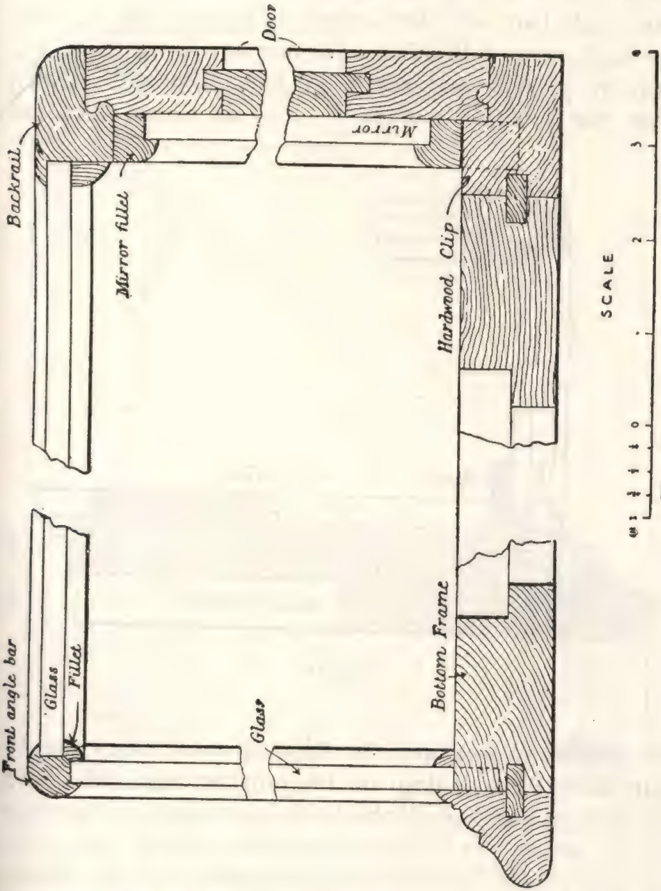


Fig. 17

must be taken out for enabling the small fillets which secure the glass to be easily screwed into their respective positions.

Framework for glass. Plane up the stuff for the round angle-bars, gauging it to 9/16 inch square, and rebate ⅛ inch deep and ⅛ inch from the face edges. The angle bars will then appear as seen in Fig. 2. For the back part of the frame, square up the stuff to 1½ inch by ¾ inch and rebate ¼ inch deep and ⅛ inch from the face for the glass. For the doors, take out

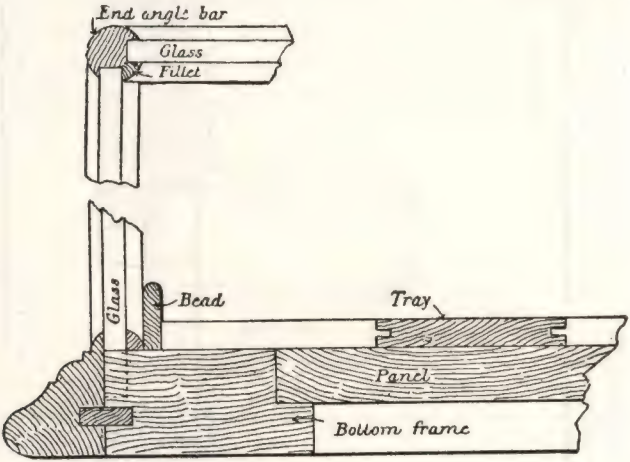


Fig. 18.

the rebate ¼ inch deep by ⅝ inch wide; bevel the rebate to 5/16 inch deep on the outside edge (as shown in Fig. 21), and work the hook-joint plane on the edge of the rebate. It is best to make the mitred joints first, as they require careful fitting together, and the bottom ends can be afterwards easily taken to the required length and cut.

Fig. 23 contains isometrical projections showing the

joints at the intersection of the front and the end angle-bars with the upright angle-bar. The position of the point is shown at A, Fig. 23.

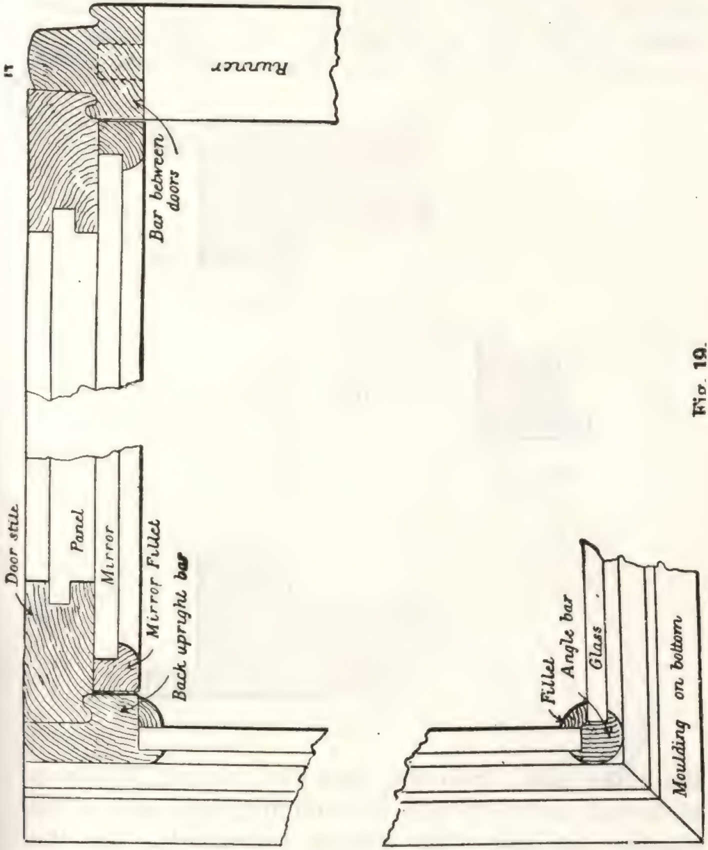


Fig. 19.

Three pieces of the required section, Fig. 20, should be got out, and the joint worked as follows:

Commence with the front and end angle-bars, cutting

a square mitre, 45 degrees on each outside face of both bars, bringing the external angle to a point, as shown in the sketch. Cut the mitre down to the rebate line and cut the surplus away, leaving the core of the bar projecting, which will be the part C. The internal part of the mitre E is the sight line. Square down and across

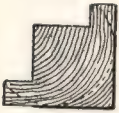


Fig. 20.

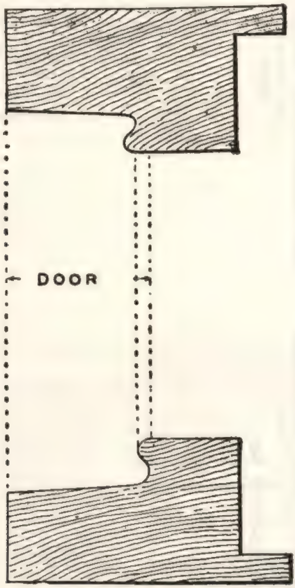


Fig. 21. Fig. 22.

the core; then, from the sight-line, measure distances of 1/8 inch and 7/16 inch; the resulting lines will be the shoulder and end of the dovetail respectively. Cut the core off at the longest line and form the dovetail as shown in the sketch, when the two bars can be fitted together.

Proceed with the upright angle-bar. Cut the square

mitre as before, but instead of cutting to the depth of the rebate, it must be cut 1/32 inch less. From the

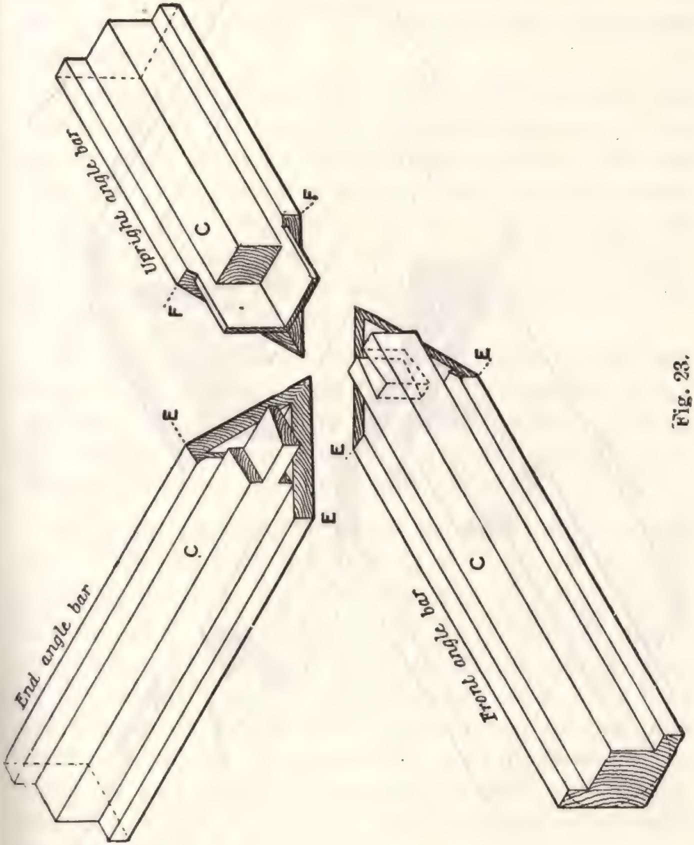


Fig. 23.

sightline F measure the same distances as before, viz., ⅛ inch and 7/16 inch. Cut off at the longest line, taking care not to cut through the projecting point of the

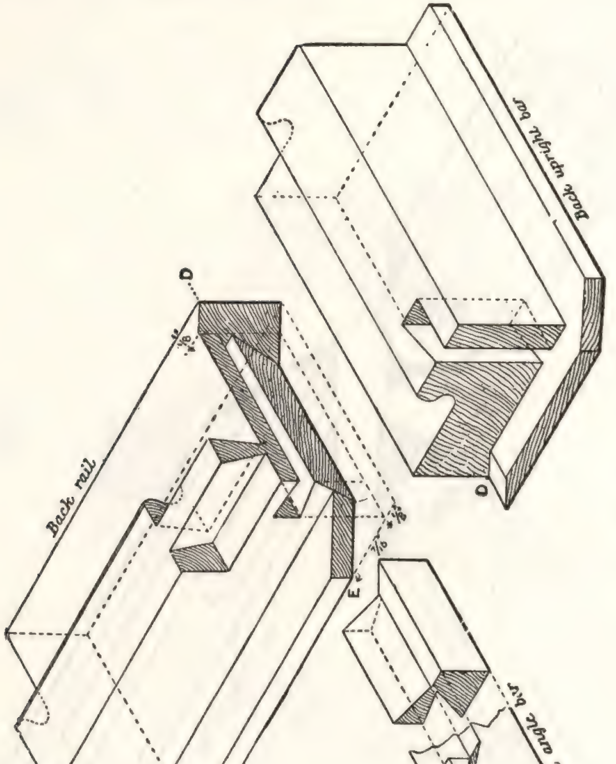


Fig. 24.

mitre, then take out the core C back to the shoulder line, thus leaving a thin tenon as seen in the sketch. Cut the tenon back 1/16 inch on each edge and continue the mitre through.

It will now be necessary to mortise the front and end bars to receive the tenon on the upright angle-bar. For the mortises, square a line across the mitre 1/16 inch from the sight line E. Gauge a line down the mitre 3/32 inch from the face of the bar, leaving 1/32 inch (the width of the mortise) between the core of the bar and the gauge line. The depth of the mortise will be to within 1/8 inch from the other face.

The work must be done very carefully, and great care taken to have the tenon on the upright angle-bar of the thickness stated, viz., 1/32 inch, as the result of having it of greater thickness would be that, when the bars were rounded, it would work through to the face.

The front angle-bar will have the same joint on both ends. The joint at the back of the case on the end angle-bar is cut as shown at Fig. 24. The joint at the bottom end of each upright angle-bar is simply a square shoulder cut to the depth of the rebate, leaving the core of the bar projecting to form a stump tenon. The bars are afterwards mitred with the moulding on both the front and the end, the projecting round of the moulding being cut away between the mitres in order to allow the shoulder to butt on the first square member, which will be flush with the bottom.

Fig. 24 contains isometrical projections showing the joints used to unite the back rail with the back upright angle-bar for forming the door opening; and also the end angle-bar. The position of the joint will be clearly understood by referring to B, Fig. 13.

It will be well to follow the same system as in the last group of joints, i. e., to prepare a piece of the required section of back rail, Fig. 21, which, when cut into two parts, can be used for both the back rail and back angle-bar; the only difference in the section of the two being that the back rail is rebated 1/16 inch less than the thickness of the doors instead of ⅛ inch less as in the back upright bar, Fig. 22. The reason for this is to allow the

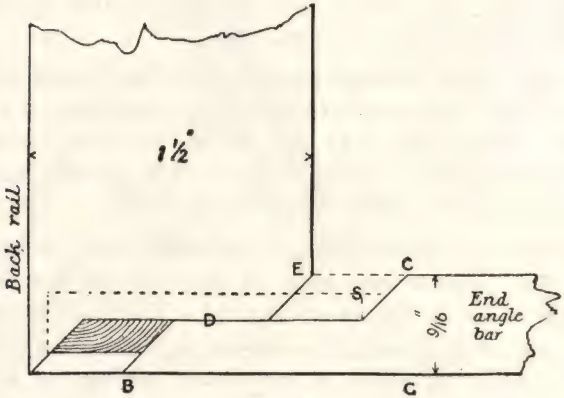


Fig. 25.

round of the hook-joint on the back upright bar to project over the hook-joint on the back rail which butts against it. It also allows a continuous hollow on the edges of the doors, which would not be the case if the rebates were kept flush with each other.

The end angle-bar is dovetailed into the back rail and is also mitred both at the extreme end and at the rebate. Fig. 25 shows the plan of this joint. It will be observed

that the joint has been left open to show the bevel from the shoulder line to the dovetail on the back rail, as at A Fig. 31.

The back rail is also dovetailed to receive the upright bar. If the reader will look at Fig. 24 and imagine the upright placed into position on the back rail, he will notice that D D meet and form the remaining part of the

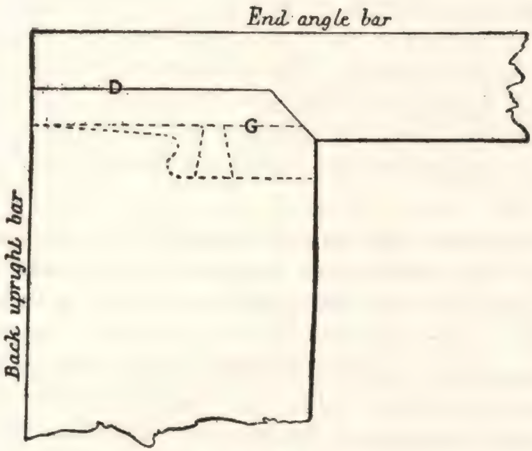


Fig. 26.

mitre, leaving a shoulder and mitre to join the end angle bar when in position. The exact position of the latter is seen in Fig. 26, the dotted lines showing the position of the dovetail on the back rail.

We will now proceed to set out the work.

Commencing with the end angle bar, square off a line for the extreme end of the mitre at B, Fig. 25, and measure back the width of the back rail (namely 1½

inch) to C, which will be the sight line. From the sight line set off 5/16 inch for the shoulder of the dovetail as at S, Figs. 24 and 25; then set off 1⅜ inch from the sight-line to the end of the dovetail. Set a gauge to the centre of the angle-bar for the shoulders, as at D, Figs. 25 and 26. The shoulder at D, Fig. 25, is cut under on the bevel as shown in the section through the joint at A, and in the sketch of the end angle-bar, Fig. 24, where the drawing is broken. It is necessary to bevel it in this way in order to obtain the requisite strength in the dovetail. The shoulder on the side, Fig. 26, is cut square, as shown in the sketch. Mark the mitres, cutting from the sight-line to the shoulder line. The mitre on the extreme end is cut through as shown in Fig. 25.

To set out the back rail as shown in Fig. 24, square a line for the extreme end of the mitre, and from this line measure back for the sight-line, namely, 9/16 inch, the width of the angle-bar, as at E, Fig. 25. Square a line between the two lines obtained, at an equal distance from each for the shoulder D. From E measure 7/16 inch toward the end of the bar, and cut off square to within ⅛ inch of the outside edge; this is clearly shown in Fig. 24.

To mark the dovetail of the end angle-bar, make a thin hardwood or zinc pattern to fit the dovetail on the angle-bar and apply it to the rebate of the back rail, cutting the dovetail out very carefully to within ⅛ inch of the outside edge. On the top side of the rail mark the external mitre from the extreme point to the shoulder-line, and cut as shown in Figs. 24 and 25. Before the mitre can be completed, the bevel must be cut along the shoulder-line and edge of dovetail, and must work

out against the mitre. The internal mitre is cut from the sight-line.

There now only remains the cutting of the dovetail to receive the upright bar. Referring to Fig. 24, it will be seen that it is necessary to obtain the shoulder-line only, which is accomplished by measuring from the extreme point of the mitre, D, Fig. 24, ¾ inch, the thickness of the upright bar. The position of the dovetail-joint between the back rail and the back upright bar is shown by the dotted line in Fig. 26.

Exact lines for setting out the back upright bar, Fig. 26, are found as follows: Square the shoulder-line D and set off for the back shoulder ¼ inch as shown by the dotted line G. The back shoulder is then cut off to within ⅛ inch of the face, as in the sketch, Fig. 24. Make a pattern to fit the dovetail on the back rail, and apply it to the back of the bar. Mitre the ¼ inch projection on the outside edge, and also mitre the inside as shown.

It is absolutely necessary that the whole of this work should be executed very carefully and very neatly. When the above mentioned joints have been fitted, make the bars to the required length.

To set out the bottom end of the back upright bar, cut the face shoulder square and mitre with the moulding as previously described for the front angle-bar. Allow the back-shoulder to be ¼ inch longer, so as to fit the rebate for the doors, the tenon being in the position shown by the dotted lines in Fig. 17.

After all the joints have been made, round the angle-bars and the back rail. The external angles of all upright angle-bars must have the rounding turned out about ½ inch above the bottom shoulder, leaving the

bottom part of the bar square to follow the line of the moulding. The joints can now be glued together and cleaned off.

The double-rebated upright bar between the doors, as at H, Fig. 19, is cut to give both the top and bottom rebate, a small dovetail being cut at both ends in the positions shown by the dotted lines. The front edge of the bar is slightly rounded to break the joint between the doors. From the inside of the bar a runner of the same thickness as the bar is screwed to the bottom of the case to keep the trays in position.

Doors. There is nothing special to note in framing up the doors; they may be either tenoned or dowelled together. The panel is prepared flush on the inside.

Carefully fit the doors to the opening and work the hook-joint on the top edge and both ends. It will be remembered that the hook-joint must be worked through on each end; and also that it is deeper than the hook-joint on the top rail. In working the small hollow to fit over the fillet on the bottom edge, work the plane from the back side of the door.

Hinge the doors on the bottom edge, fixing the butts against the outside edge of the half-round fillet. When fixed thus the airtight joint will remain intact. The doors are fastened by a spring catch or lock let into the top rail.

When the doors are hung, the position of the mirror fillet can be marked by lining down the back of the doors round the frame. The fillets should be fixed 1/32 of an inch inside the lines to allow for clearing.

Trays. A cross section of the tray is shown in Fig. 18. The bottom is prepared for three pieces of ¼-inch pine. The grain of the centre piece runs from back to

front of the case, the grain of the side pieces being at right angles to it, and the three pieces are tongued and grooved together as shown. Glue the pieces together, and, when set, mitre the bead round the bottom.

Another method of ensuring the bottom against warping is to have the bottom in three thicknesses, the grain of the centre lying across the two outside pieces, and the pieces being glued together.

The inside of the tray and over the bead are covered with velvet or some other material, which must be glued to the tray. Glue should be used sparingly so as to prevent it penetrating the material.

CIRCULAR-FRONTED COUNTER-CASE WITH GLASS ENDS.

Fig. 28 shows a cross section through a circular-fronted case with glass ends. The only difference in the construction of this case from that of the square case is the bent angle-bar, and, of course, the omission of the front angle-bar.

In making this case it is first necessary to have the glass bent to the shape required. For this purpose a pattern of the curve should be sent to a glass manufacturer. When the glass has been received make a mould of the same shape, on which to bend the angle-bar, as shown in Fig. 29. The convex side of the glass will give the rebate line from which to work the mould.

Use birch for the angle-bar, as it bends easily; it can be stained to match the other part of the case. Have the bar long enough to bend from the bottom of the case to the back rail.

To bend the bar successfully, cut the top side of the bar away down to the rebate line on the end required

to be bent. The length of the part cut away will be from the bottom of the case to a little beyond the springing line. Care must be taken to cut the two bars for

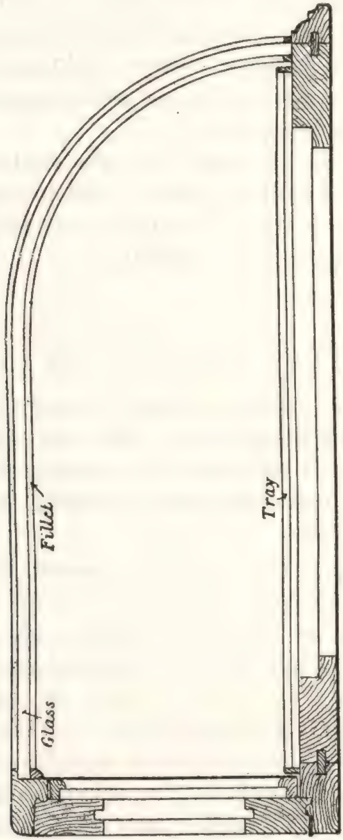


Fig. 28.

the case in pairs. Steam the bars for several hours and then bend them round the mould (Fig. 29) by securing the extreme end first with a cleat, as shown at A. Draw

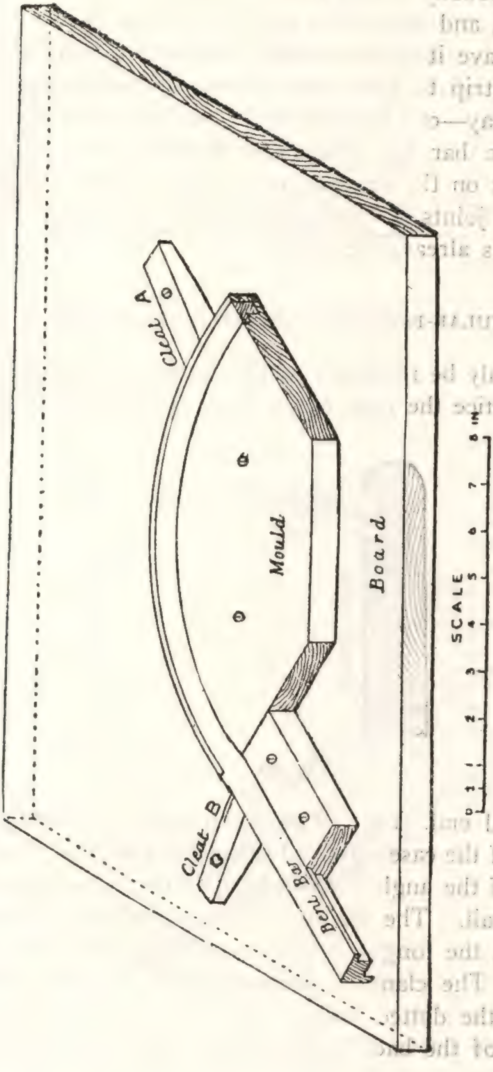


Fig. 29.

the bar gradually to the mould, secure it in position by the cleat B, and leave it to cool for several hours. It is better to leave it on the mould until the following day, when the strip to form the rebate—which replaces the part cut away—can be fitted and glued in position.

After the bar has been bent and the strip cleaned off, place it on the drawing-board and set out the position of the joints at the bottom of the case and on the back rail, as already described.

CIRCULAR-FRONTED CASE WITH SOLID ENDS.

It will only be necessary, after the preceding explanations, to notice the joint of the back rail, and the section

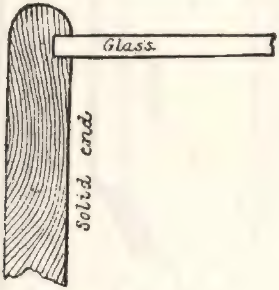


Fig. 30.

of the solid end. Fig. 30 shows a section through the solid end of the case, grooved to receive the glass. Fig. 31 is a plan of the angle formed by the end of the case and the back rail. The clamp A is tongued and grooved to the end, the tongue being stopped ½ inch below the top edge. The clamp is prepared with a hook-joint as shown by the dotted lines. The width of the clamp is the width of the back rail less the rebate for the glass.

Fig. 32 shows in isometrical projection the joint at the junction of the back rail with the solid end. Imagine

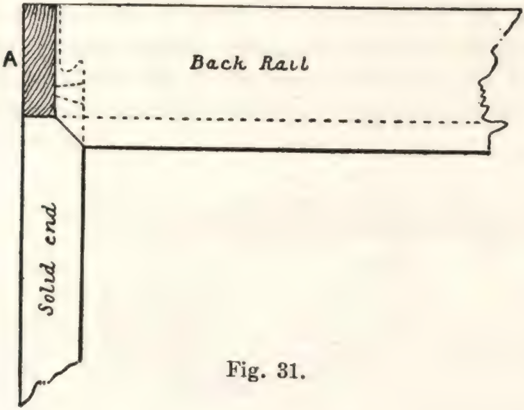


Fig. 31.

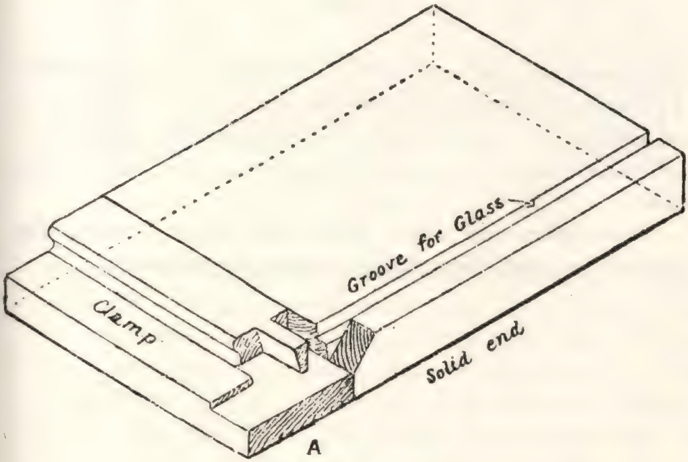


Fig. 32.

that A A are brought together. It will then be seen that they slide into position and present the appearance

shown in the plan in Fig 31, and give the extra lines for setting work.

The solid ends are ⅝ inch thick, finished size. They must be left wide enough to screw to the bottom frame of the case. Fix the moulding round the bottom and mitre it at each inside round of the ends, as before described for upright angle-bars, turning the round on

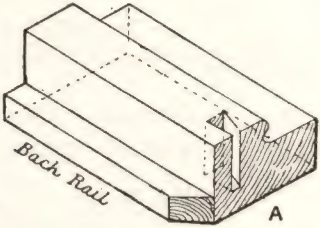


Fig. 33.

the outside of each end out ½ inch above the moulding. The moulding mitred round the ends of the case must be reduced by the thickness of the quarter-round member which forms the rebate for glass at the front of the case.

These cases are often fitted with several trays, the bearers to carry them being screwed to the ends.

SOME FORMS OF PANELS.

We conclude this Volume by giving some illustrations of panels. In Fig. 1 we give a "flush" panel for a front or entrance door, in which in front elevation a, b, are the two rails, d d, e e, the stiles, c c, g g, the panel with

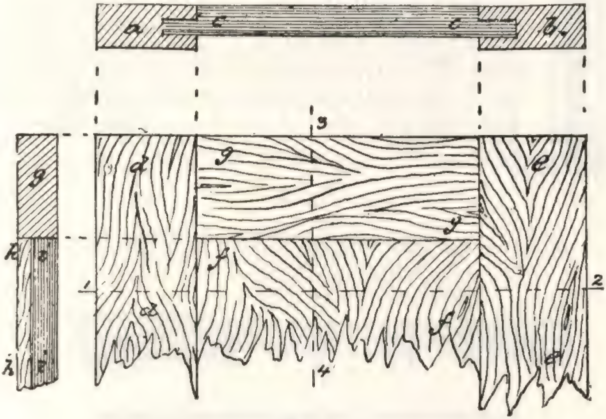


Fig. 1.

stuck-on mouldings all round and mitring at corners; g h is a vertical section in line 3 4. In this the recess between the stile and panel is one side only. Where there are recesses on both sides of the panel b b, Fig. 2, and the stiles a a, the panel is known as a "square" panel. In this figure the lower diagram is front elevation; that on the left is a section on line 3 4. In Fig. 3 we illustrate different forms of panels. In the upper diagram, a a, the stiles carry one "square panel,"

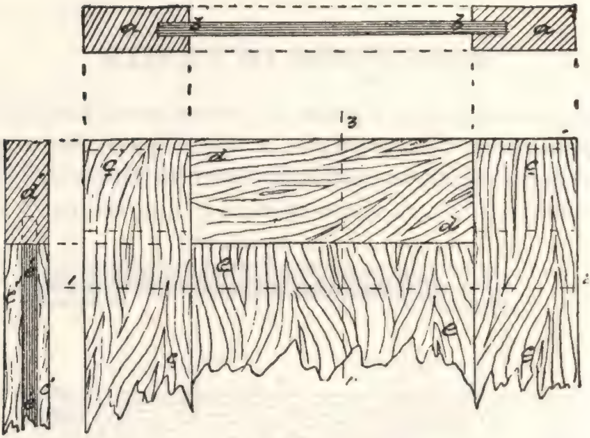


Fig. 2.

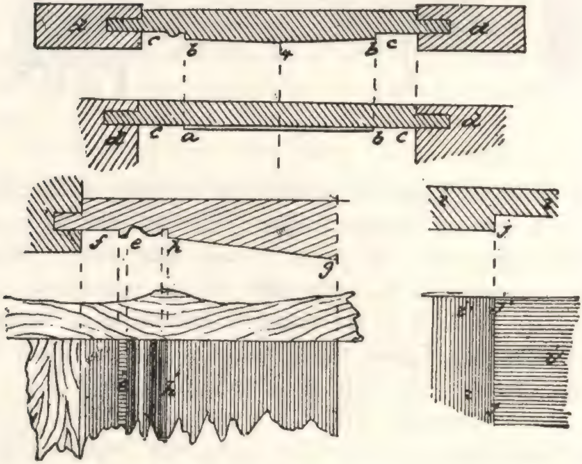


Fig. 3.

which is not flat, as in Fig. 2, on the inner side, but tapers to the centre, which is thickest, to the sides,

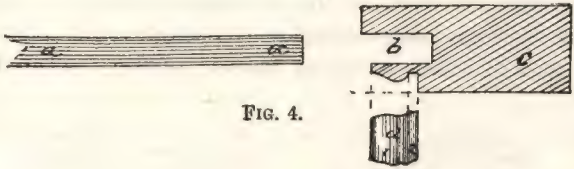


FIG. 4.

where it may be either square, as at the right hand, or finished with a moulding, as on the left.

Resuming our description of the drawing named, the second diagram shows a "flush panel," with stiles d d,

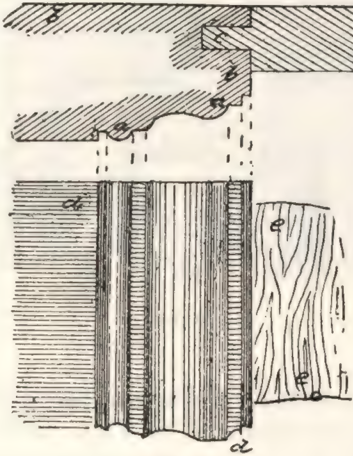


Fig. 5.

the panel having a raised position in the centre, as shown at a b, with flat spaces as at c c, all round. The

lower diagram to the right is an enlarged view in section and elevation of the part of the panel of upper diagram to the right. The lower diagram to the left is an enlarged view of the left hand side of the panel, which is technically called a "raised panel." Figs. 12 and 13 are other views of raised panels, and diagram

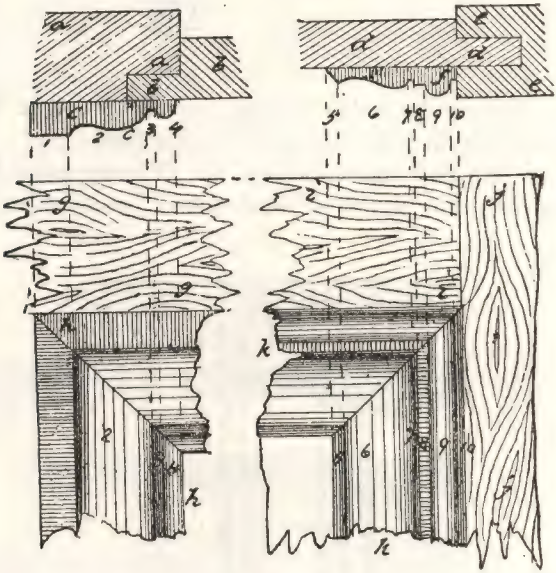


Fig. 6.

B in next figure shows a form of panel in the Gothic. Other forms are illustrated in Figs. 8, 9, 10, and 11. In Fig. 3 the flat part of the panel surrounding the raised central part is called the "margin." (See also Fig. 12 at b.) The panel, as in Fig. 3, is called a "moulded raised panel" when there is a moulding at

the margin, as f e h. There are other distinctions in panel work, yet to be noticed. In "flush panels," as in Fig. 1, the "moulding" or "bead" is worked only on the two sides (vertical) of the panel, as at d d, Fig. 5, and these terminate at the rails, as at f f, no moulding being at the ends of the panel. This is called "bead butt" panel. When the panel has mouldings all round,

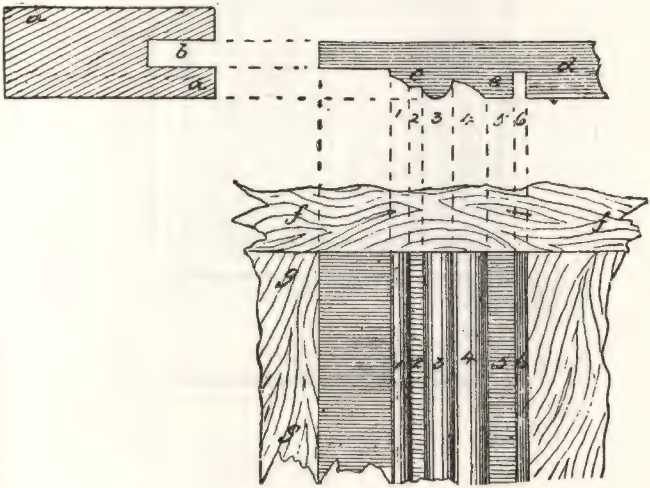


Fig. 7.

that is at top and bottom as well as at the sides, the mouldings meet at the corners and are mitred, as shown in the lower part of the diagram in Fig. 6, this is known as a "bead flush panel." In panel work where a moulding is worked out of the solid, as at b in Fig. 4, or at a a in Fig. 5 of the style, as c c or b b, the term "stuck on" (a corruption of "struck on," which

is the true term) is applied. This is only applicable to "bead and butt" panel work vertically, as the mouldings would not mitre if struck horizontally on the rails.

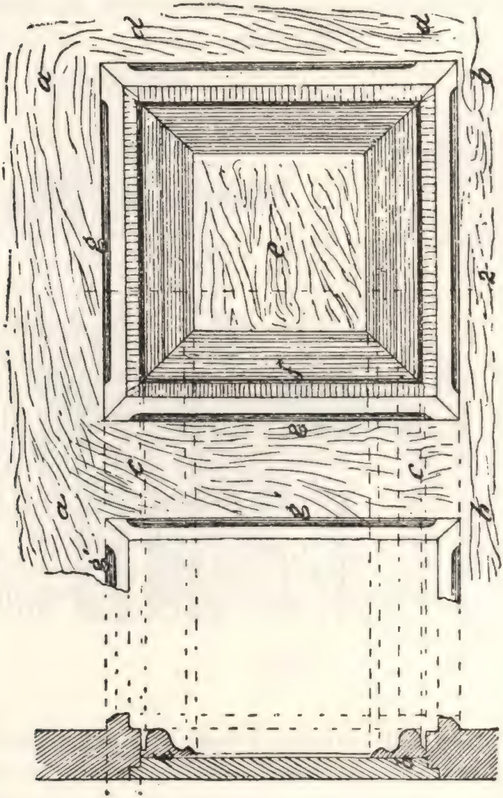


Fig. 8.

When the mouldings are made separately and nailed onto the stiles j j, and rails i i, Fig. 6, they are called "laid on" mouldings. They may be nailed on either to

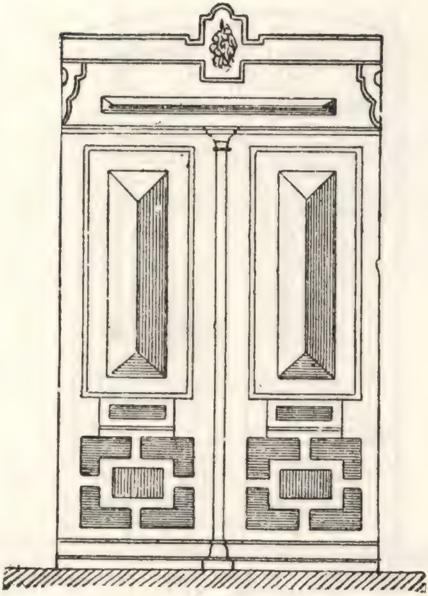


Fig. 9.

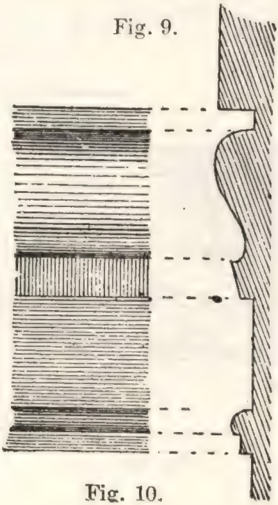


Fig. 10.

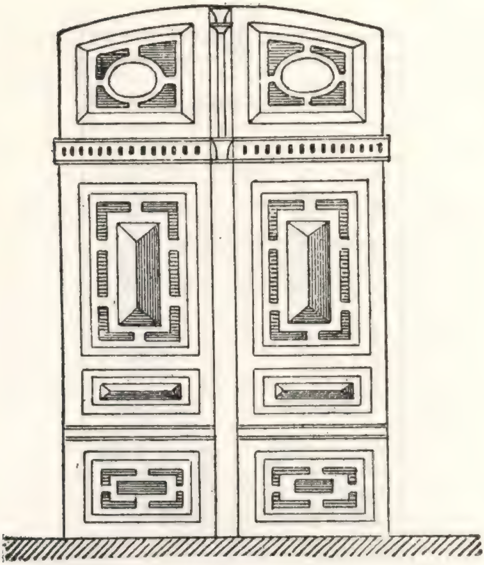


Fig. 11.

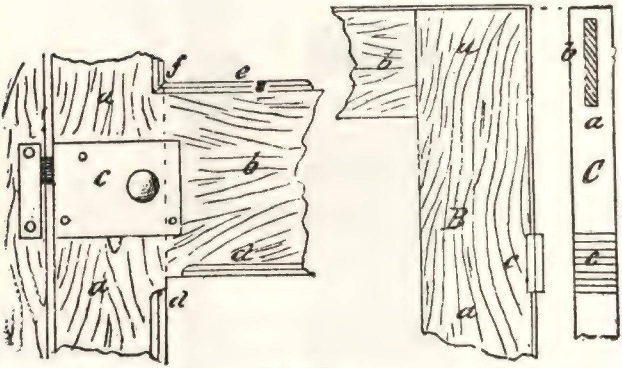


Fig. 12.

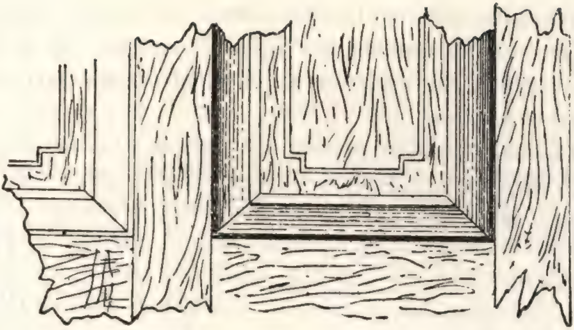


Fig. 13.

Fig. 14.

the stiles and rails or to the panels in "flush" work, or all around the panels in "square" panels. In Fig. 14 in diagram A, we give a panel at upper part of

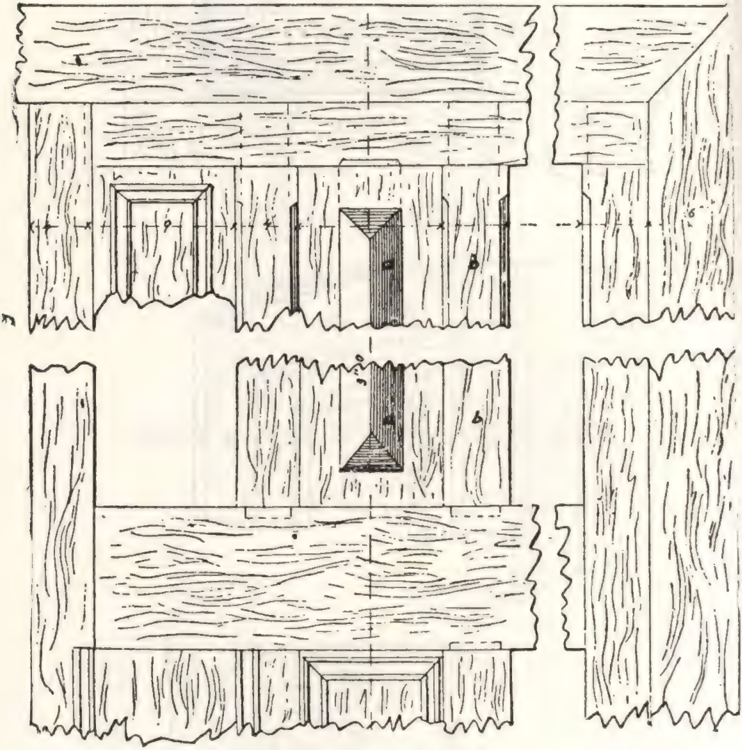


Fig. 15.

door, in which the upper rail a a is curved at top, b b b the stiles, separated in the centre by a moulding a a d the upper panel, with stuck-on mouldings c e e. Diagram B is front elevation of lower panel. In Fig. 13

we give a section of middle stile and panel; the middle stile b b being provided down the centre with a stuck-on moulding, as at b a, corresponding to the vertical moulding a a in Fig. 15. A moulding as at c c is worked in the margin of the stile corresponding to c c in Fig. 14. E shows the moulding in section stuck on the square panel f g, the margin f being in this way wide. In Fig. 15, and in Figs. 8, 9, 10, 11 and 12 we give illustrations of panel work, and in Fig. 9 section and elevation of mouldings for a panel.

JOINERS' WORK IN THE CONSTRUCTION OF DOORS—DIFFERENT KINDS OF DOORS.

We now come to illustrate the different forms of doors, and various details of their construction. Doors are either external or internal and both may be con-

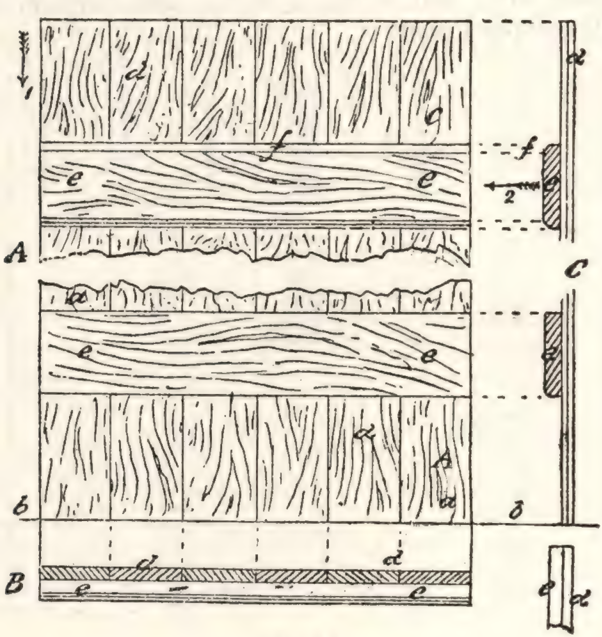


Fig. 16.

structed much in the same way. The chief difference between them, if difference may be made at all, is that external doors are heavier in their timbers—that is,

thicker and broader—and are not quite so much ornamented with mouldings, or so highly and carefully finished, as internal or private room doors. Doors are of different classes, beginning with those adapted either for houses, of a simple character or for out-buildings, etc., where economy is carefully studied, and going up to the more elaborate forms, used in houses of the higher class.

The simplest form of doors is shown in part elevation at A, Fig. 16, in plan at B, looking down in direction of arrow 1, in C side elevation or edge view looking in direction of arrow 2. This form is what is called a "batten door." In elevation in diagram A, the lower part is a a, next to floor or ground line b b. The door is made up of flat planks, a a c d d, running vertically from foot or floor, or ground line b b up to head. These are either laid as in plan B in the cheapest class of work, edge to edge, and held together by cross pieces, or bars, e e. In better work, these and the vertical parts, d d, are secured by joints of different kinds. In the section C the cross bars e are simply laid flat and nailed to the upright planks, d d. The edges of the cross-bars, d d, may either be left square, or have the lines or corners planed off and "chamfered" or beveled off as at f f.

BATTEN AND BRACED AND BATTEN, BRACED AND FRAMED DOOR.

Fig. 17 is an elevation in diagram A of a "batten and braced" door. To the vertical and cross bars of the simple form in Fig. 16 the diagonal "brace" a a a a,

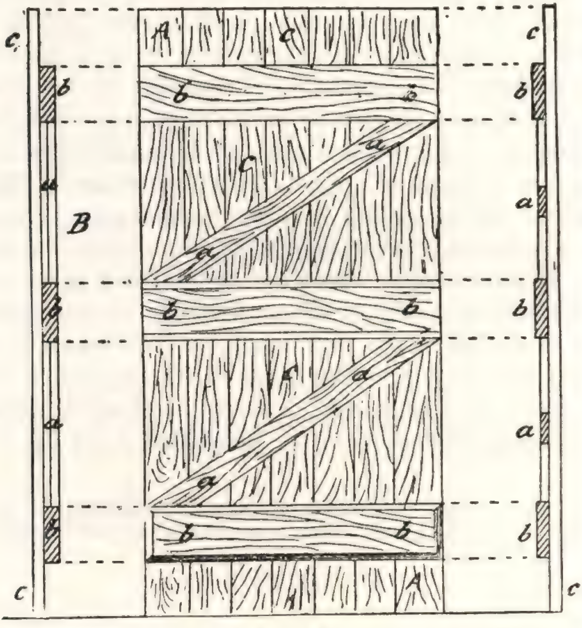


Fig. 17.

corresponding to the struts of a roof truss, are introduced; these butt against the cross bars or battens **b** b b b, while behind are the vertical boards c c c **c**,

Diagram B is side elevation or edge view and C vertical section. A still higher class of door is the "framed

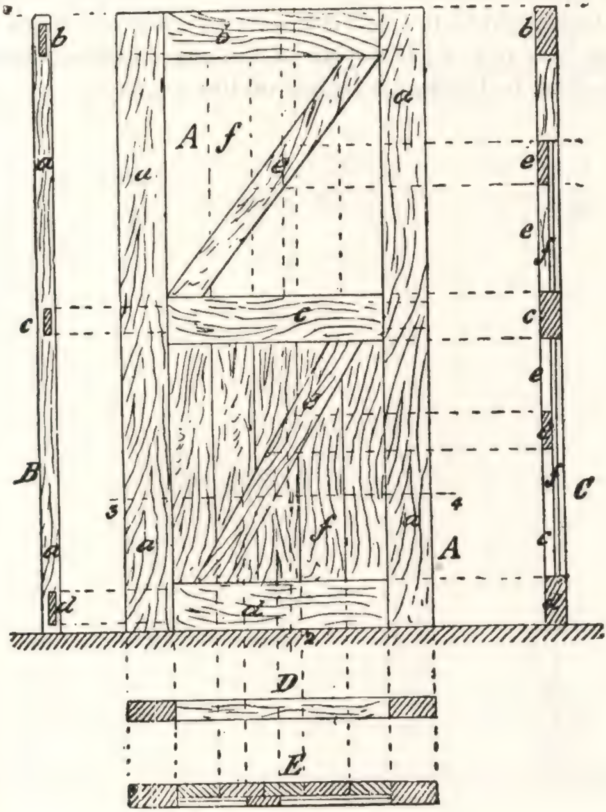


Fig. 18.

braced and battened" door, in Fig. 18, here as in elevation in diagram A, we have an outer frame vertical

pieces, held together and secured by the cross-bars b, c, d, the ends of these being tenoned into the stiles a a. The central spaces are filled with braces e e, and the vertical boards f f. Diagram B is vertical section on line 2 and C is side view showing ends of tenons of cross bars b, c, d; D is plan of top edge, looking down; E is cross or horizontal section on line 3 4 in A.

PANELLED DOORS—NAMES AND OFFICES OF DIFFERENT PARTS—STILES—RAILS—MORTISES.

The transition from this form of door to the highest class, the "panelled door," is easy and natural. We have

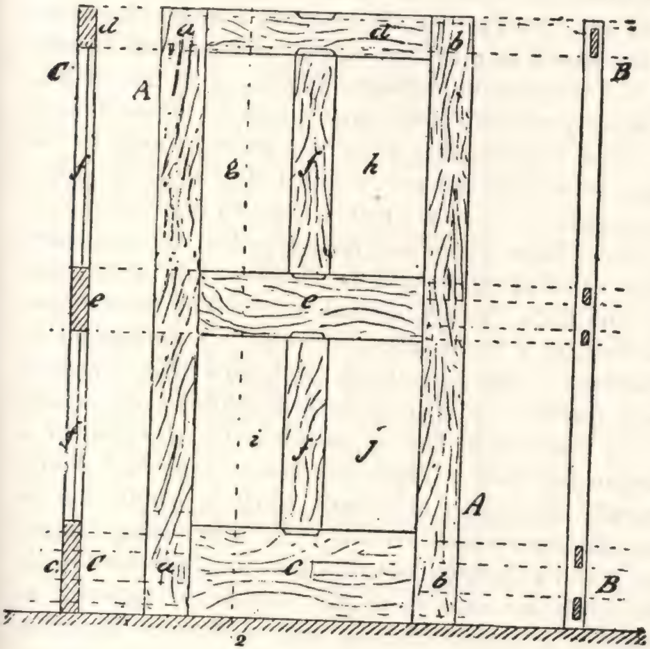


Fig. 19.

seen in the simplest timbers, which is the element of the "truss," and which gives the strongest form attainable.

In this view the panelled door, as in elevation in A, Fig. 19, is not so strong as the form in Fig. 18, from the absence of the diagonal braces, as e e, but those, if required in a door such as an external one, where strength is an object can be dispensed with in interior doors, which are always panelled in good houses.

Elegance or neatness of arrangement, with such ornamentation as mouldings, etc., can give, are what are looked for. In Fig. 19, the external framework enclosing the panels is made up of two side vertical boards, a a, b b varying in thickness from 1½ to 2½ inches, and in very superior work even 3 inches. These boards are called "stiles"; that by which door is hung to the casing, secured by hinges is called the "hanging stile," as a a; that to which the lock is secured the "lock stile," as b b. These stiles are held together by cross-bars called "rails" of which c is the "bottom rail," d the "top rail" and e the "middle or lock rail." The central vertical bars, as f f are called "muntins" (a corruption of mouldings). The assemblage of boards thus arranged leaves spaces as g, h, i, j, these are filled with panels, as a, b, c and d, in Fig. 20, which is the elevation of a *four*-panelled door. There are also six-panelled doors. Generally the panels are nearly equal in length, but in some the lower panels are short, the upper being longer. Figs. 2 and 4 illustrate outside doors in Continental style. The panels are secured to the framing by grooves, as shown in preceding figures and as further hereafter illustrated, and are ornamented with mouldings, as explained. In Fig. 19 diagram C is the vertical section, edge view of style b b. In Fig. 20 B is plan of top edge of door. The rails are secured to the styles by tenons, sometimes single, but more frequently in good work

by double tenons, as in Fig. 21, in which is front elevation of rail, a a, b c two tenons. Diagram B is part of stile a cut vertically in two to show the seats of the mortises **b** and c, diagram C and view of rail. In left-hand dia-

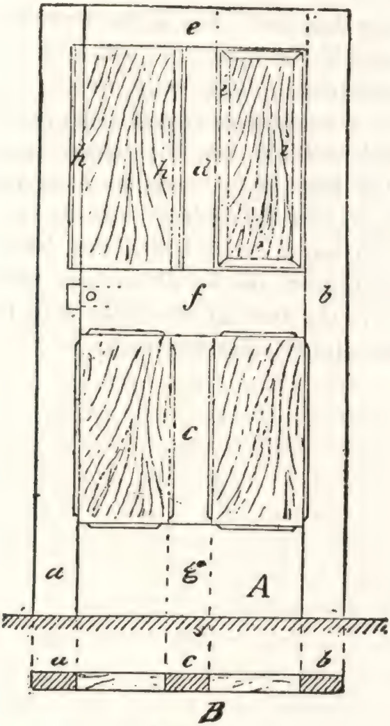


Fig. 20.

gram in Fig. 12 is elevation of part of "lock stile," a **a** and "lock rail," b of a bedroom door, with simple lock, c, known as a "rim lock." In diagram B, part of the "hanging stile," a a, of this door is given in elevation, **b**

part of "top rail," a portion of upper "hinge" is shown at c. Diagram C is edge view. The inner edges of stiles, rails, and mortises are generally, in good work, "stop chamfered" as at d d, or beveled off from end to end, as at e f, the two edges meeting in a mitre, as shown. The "top chamfer," d d, is the neatest, stopping, as it does, short of the end. A rim lock is screwed onto the outside of the lock stile; what is called a "mortise lock" is employed in superior doors, where the lock is concealed, nothing but the handle and keyhole being visible, the lock being inserted in a mortise or vacant part cut out in the stile to receive it. Fig. 29 contrasts the two locks. c d is the rim lock. In the mortise lock nothing but the handle at g is seen, and the escutcheon h, i is the bolt of the lock, a a, b b, a′ a′, b′ b′, are the chamfered stiles and rails.

DOOR CASINGS.

Doors are secured to "casings." These are of timber, and built into the walls, and are secured to wood, bricks or grounds. Fig. 23 illustrates in part elevation an outer "door casing." The sides b b, c c, are called "jambs," f f, the "head," into which the jambs are tenoned, the feet being also tenoned, at d, into the upper part of stone step a a. Fig. 22 is sectional plan showing arrangement and relative positions of various parts of a door and its casings. The door, l l, is hinged to the "jamb" b, this being secured to the "ground" or "wood brick" a a, bulit into the wall b b, c and j are the "architraves." The opposite "jamb," f f, is rebated as at m to allow of a space into which the "door lock stile" falls, as shown by the dotted lines, which represent the lines of the door. The outer edge of the jamb may be left plain, but is often finished off with a "quirked head," as at j; k, k, the hinge. The inner and outer architraves are at c and j; a a, the wood brick; b b, the wall; e, i, are the elevations of the architraves, d and h. The elevations of these two parts of sectional plan of door fittings are given in the under part of the drawing in Fig. 23. The edge of the door a, as looking at it from the inner side, is shown at p p, q q, being the ends of tenons of top rail, r r, the hinge, n n, from a view of architrave, o o the wall in the void of which the door is hung. In the under drawing to the right, part of front surface of door is shown, s s, the architrave, t t the wall.

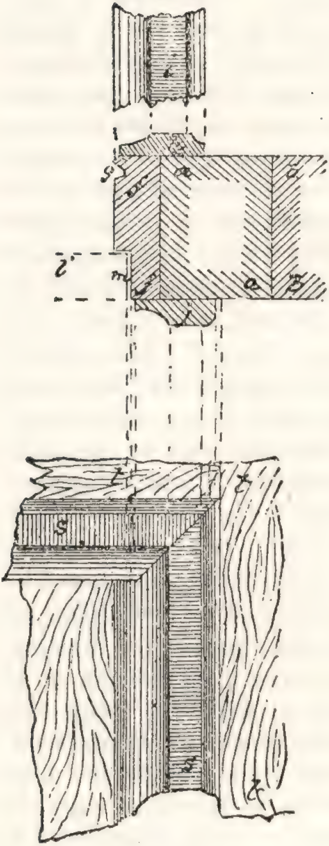


Fig. 22.

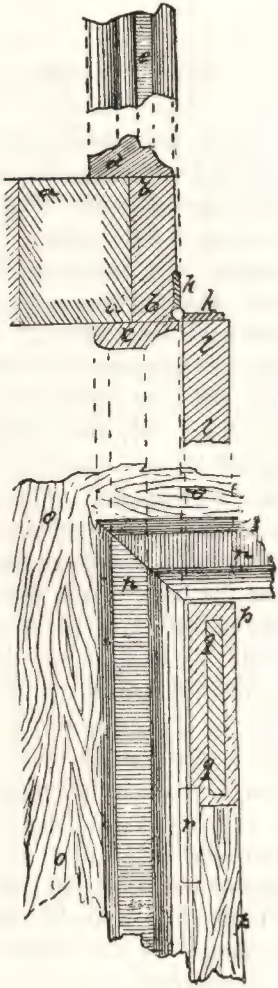


Fig. 23.

JOINTS OF STILES AND RAILS IN PANELLED DOORS.

Figs. 24 and 25 give illustrations of methods of joining rails and stiles, or rails and mortises. Let a b c d, Fig. 24, be the stile, with moulding stuck on edge; f g h is part of the rail, with tenon f, shown by dotted lines

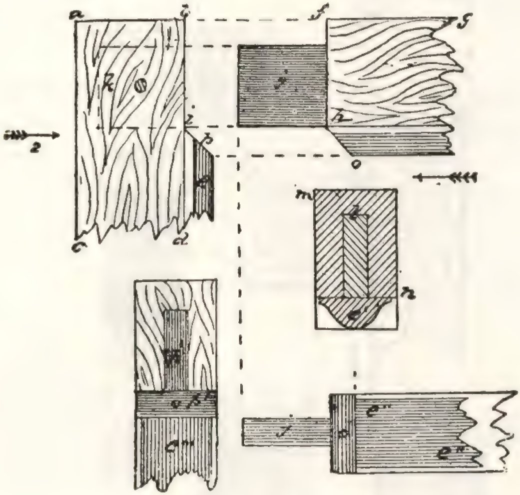


Fig. 24.

in stile a b c d. Front view of tenon are face of mitre of chamfer at p, looking at a b c d in the direction of arrow 1, is shown in the lower diagram at k′, p′ and e″. The section of part f g looking at its end, in direction of arrow 2, is shown at l m n; the section of a moulding

is in this at e′. In lower diagram to the right is given a view of under side of rail f g. In Fig. 25, a a, is

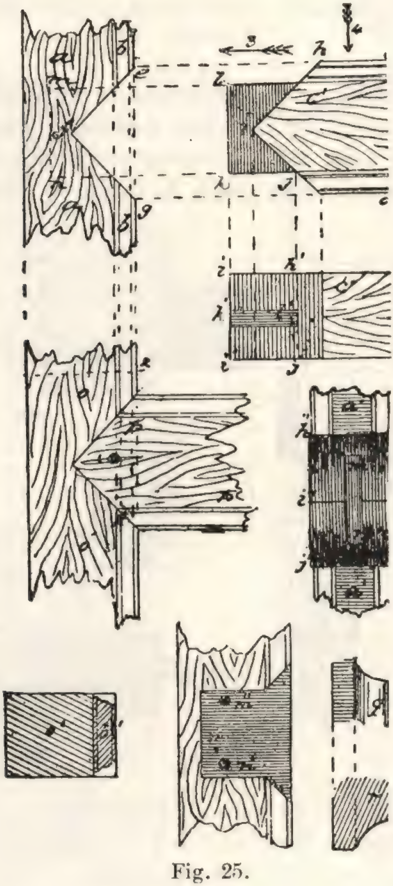


Fig. 25.

front view of part of stile with moulding worked on edge, at b b; part of rail is at c′ c′ d. The angular

face of part cut out in stile e f, fg corresponds with angular end h i j of rail, but a tenon i l k is left on, or is inserted in end of piece c′ c′ d. The end view of the stile a a, looking at it in the direction opposite to that

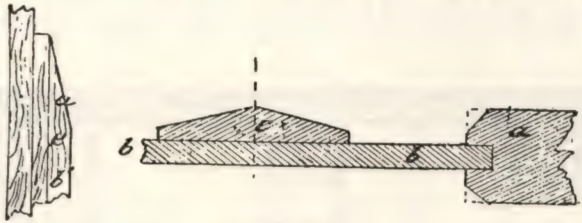


Fig. 26.

of the arrow 3, is shown in the middle diagram to the right with corresponding letters accented, showing corresponding parts. The line i″ i″ corresponds to the line at point in rail c′ c′ d d. The plan of under side of rail c′ c′ d is shown in diagram immediately below k′, l being edge view of tenon k l. The finished joint is shown at o o, p p; the diagram below to the left being cross

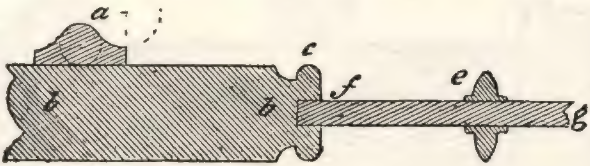


Fig. 27.

section to the line 1 2. Enlarged elevation q, and section r of moulding b b, or b″, is given at the two diagrams to the right at bottom of drawing. Another method of forming the junction is shown in the middle diagram at the foot of Fig. 25, the shaded part showing form of tenon with the ends of moulding united.

A FOUR-PANELLED DOOR.

In Fg. 28 I give a drawing—to a scale of ⅛, or 1½ inch to the foot—of a four-panelled interior or room

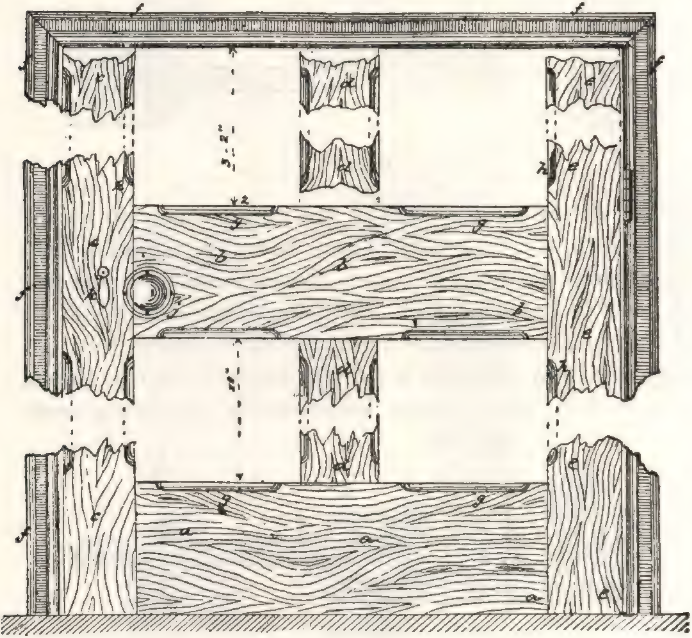


Fig. 28.

door, showing all the leading parts of the framework, with the exception of top rail, which is usually about half the breadth or depth of the middle of lock rail, marked b b in the drawing. The panels are not shown,

but the dimensions of the spaces they occupy are given. The panels are plan "square," the only ornamentation in this example being a "stop chamfer" worked on the margin of stiles, and rails, as shown at g g and h h. In the drawing a a is the "bottom rail," b b the middle, or usually "lock rail," as it carries the "mortise lock," the handle of which is shown at j. The "key hole" is covered by a movable part, hung or jointed at upper end, called the "escutcheon," or more frequently in technical talk, the "scutcheon," or "skutcheon," shown at k. The stiles are at c c, e e—the stiles c c, termed the "lock stile," being that in which the lock is mortised. The stile e e is called the "hanging stile," being that on which the door is "hinged" or "hung" to the door casing. The vertical pieces, or "muntins," which divide the panels from each other, placing them in pairs on each side of the door, are shown at d d. The door framing thus constructed is surrounded on both sides and at top by the architraves f f f.

ARCHITRAVES OF A FOUR-PANELLED DOOR.

The section of architrave in relation to the door casing or check is in upper diagram to the left in Fig. 29, a a being part of the door casing, b b the section of architrave, of which part elevation is shown at c c, 1, 2, 3, and 4 showing similar parts in section correspondingly lettered. The edge view of the "lock stile" as a a f in the figure preceding, is shown at d d; e e shows the brass plate let into the edge and secured by screw nails as shown. This is part of the lock furniture of the door, f indicating position and section of the shooting or locking bolt of the lock, which passes into the aperture of a brass plate secured to the inner side or edge of the door casing. The bolt, which secures the door, being closed —not locked—f being the locking bolt, is shown at g, this being worked by the handle j of the lock. The part of the lock furniture attached to the door casing opposite to the edge, as d d d, of the door stile, is shown in the lower diagram to the right. The part 3 3 in this corresponds to the face of the recessed or rebated part p in drawing above, cut in the face of the door casing n n n, the door passing into and resting against the face of recess or rebate p. In the upper diagram to the right, o o o is the outer architrave secured to the door casing n n n, r part of the inner architrave. The part of the lock furniture secured to the door casing is shown at t t; it is a brass plate let into the face g, or 3 3 of recess or rebate p. The aperture in this into which the bolt f of the lock passes is shown at p; that into which the bolt

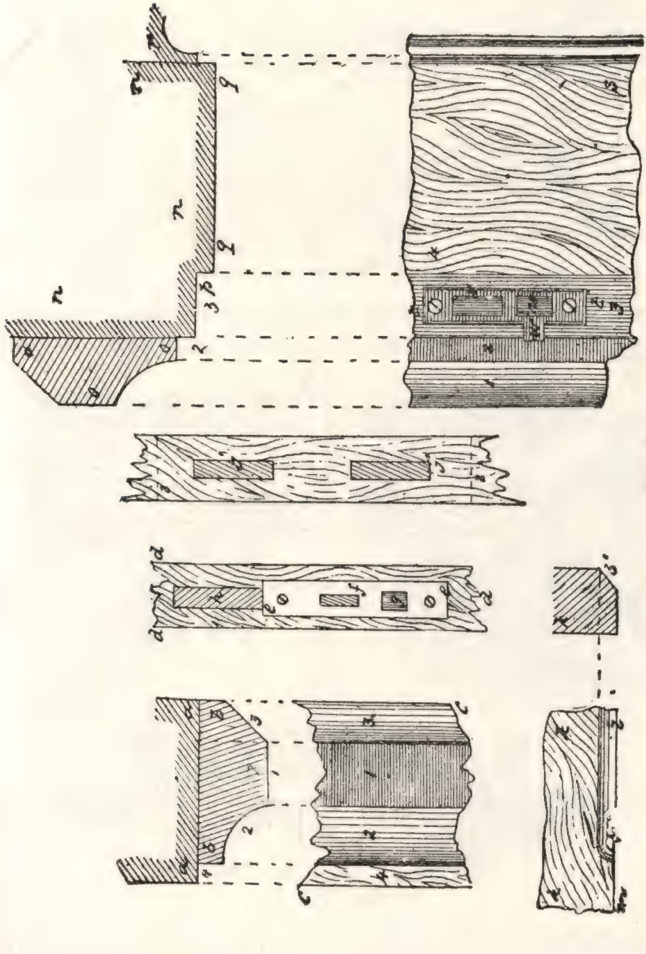


Fig. 29.

moved by the hand passes is at u, a spring w, cast onto the plate t t, being shown at w. A small projecting part

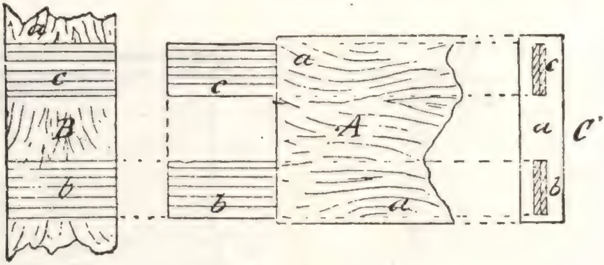


Fig. 30.

as w′, to make the opening and closing of the door more easy. The two diagrams to the left at lower part of

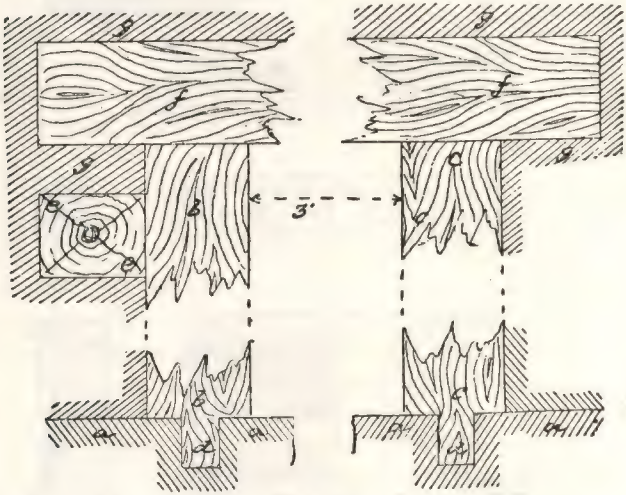


Fig. 31.

drawing show the elevation k l m, the chamfered part of framing with section at k′ k′.

SOME EXAMPLES OF ORNAMENTAL WOOD-WORK.

The following examples are introduced in order to

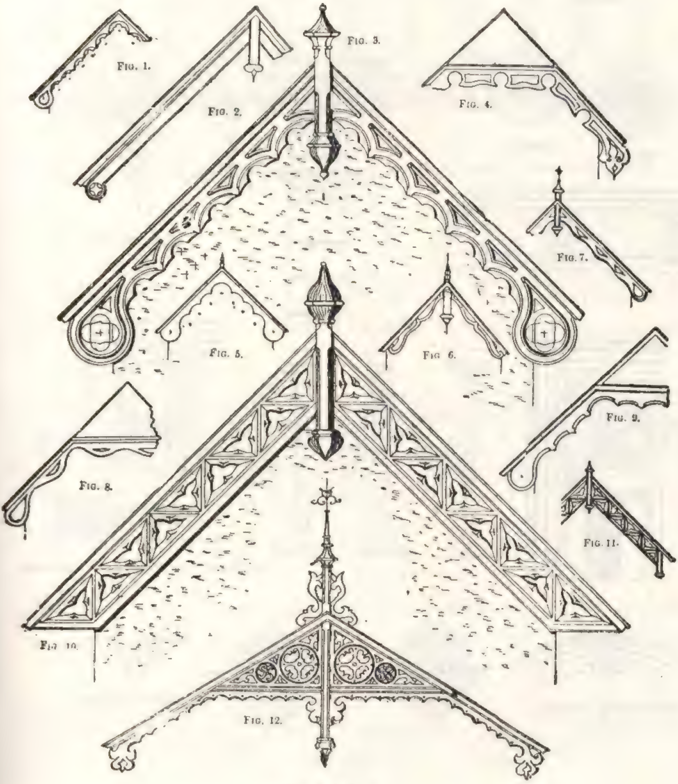


PLATE 1.

give the workman an idea of the shape and construction of low-cost ornamental wood-work. The figures

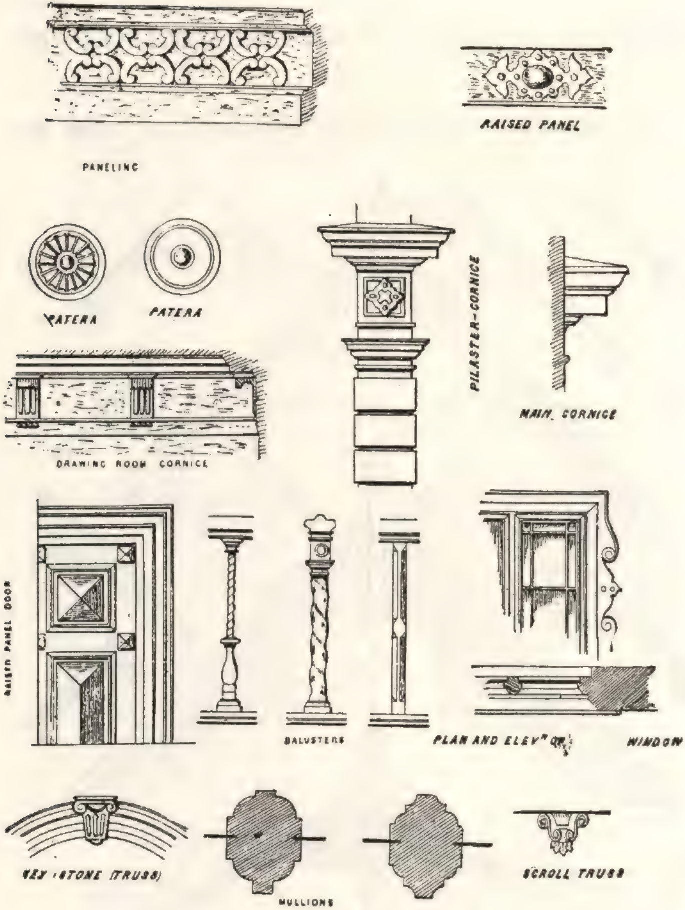
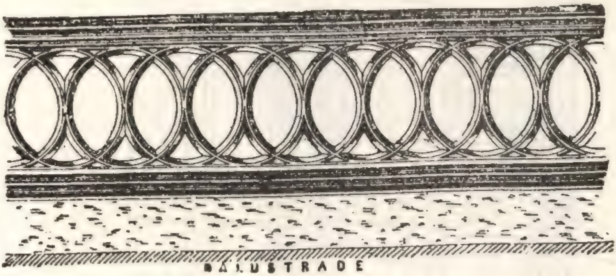


PLATE 2.

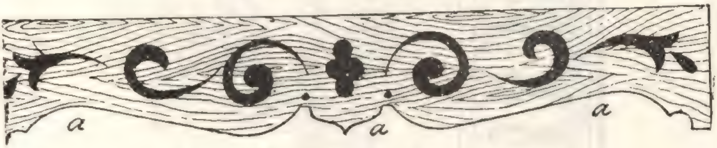
shown from No. 1 to No. 12, inclusive, exhibit a number of large boards, chiefly in Gothic style. Plate No. 2 is a style which was in vogue very much a few years ago

and was generally known among carpenters as Ginger-Bread work. It is well adapted for sea-side cottages or



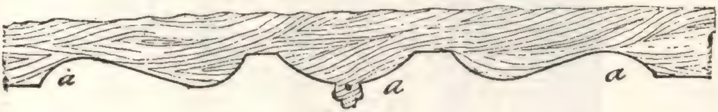
No. 13.

summer residences; it consists mostly of cutwork. Nos. 2, 5, 8 and 9 are well adapted for ordinary cottage



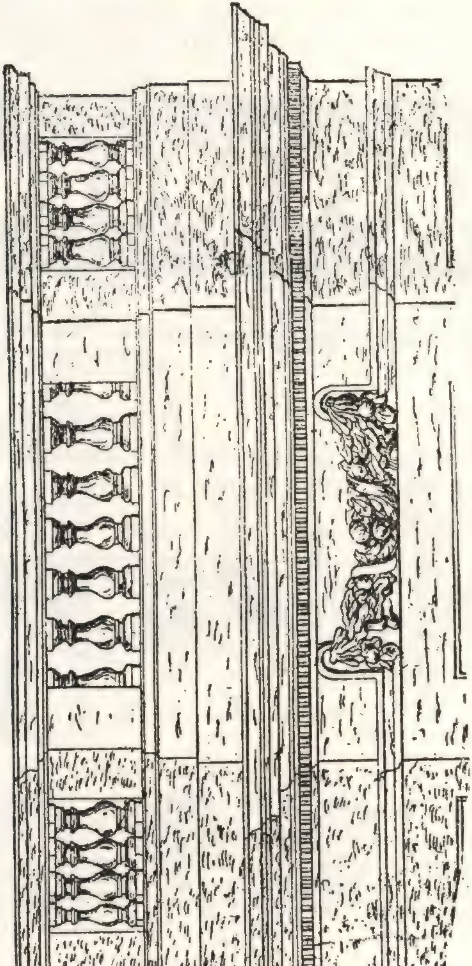
No. 14.

work. Nos. 13, 16 and 21 are well suited for balustrades, No. 16 being especially adapted for heavy balus-



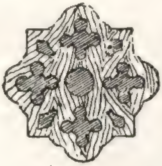
No. 15.

trades on verandas or over bay windows. Nos. 14, 15 and 17 require no explanation, as they may be adapted



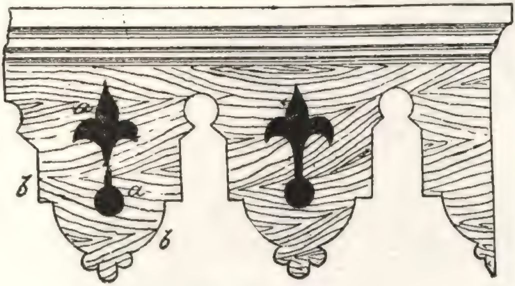
No. 16.

to a thousand different purposes. Nos. 18 and 19 make very handsome drops for verandas and other similar



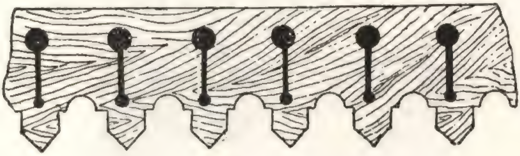
No. 17.

work. No. 29 shows a single drop with the grain of the wood running vertically. A number of these placed



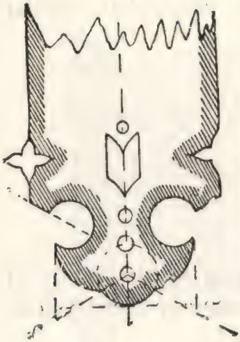
No. 18.

together edge to edge make a very nice trimming for verandas. No. 22 shows a cut bracket which will often

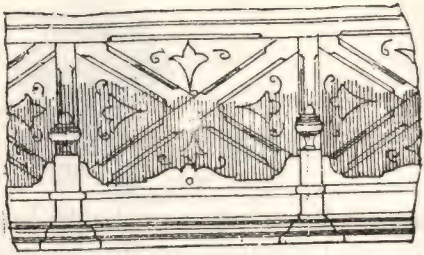


No. 19.

be found useful. No. 23 shows an elaborate railing suitable for a veranda or balcony. No. 24 exhibits a

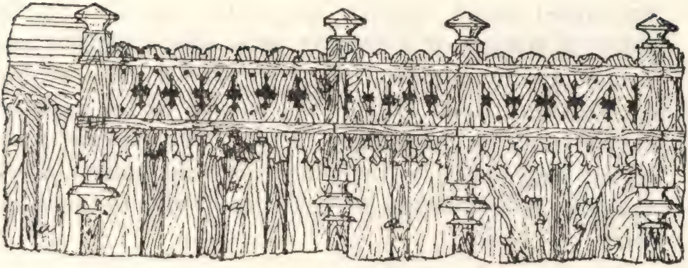


No. 20.



No. 21.

No. 22.



No. 23.

No. 24.

No. 25.

perforated panel suitable for many places. No. 26 shows a portion of a circular panel which may be perforated or the ornaments may be planted on, according to exigencies. See Plates. The balance of the examples shown speak for themselves. They offer a number of excellent suggestions to the progressive workman. These examples will doubtless prove of great value to the workman.

QUESTIONS ON MODERN CARPENTRY
VOL. I.

QUESTIONS.

1. Give definition of a "circle."
2. What term is given to a line that is drawn through center to circumference of a circle?
3. What term is given to a line drawn from center to circumference of a circle?
4. What term is given to a line (less than the diameter) that cuts the circumference of a circle at two points?
5. Give definition of a "tangent."
6. Give definition of a "segment of a circle."
7. Give sketch of a circle showing the "diameter," "radius," "chord," "segment" and "tangent."

8. Give sketch and describe how to find the center of a circle.

9. Into how many equal parts is the measurement of the circumference of a circle divided?

10. Give the three terms used in measurement of the circumference of a circle, and show how they are written.

11. What is a quadrant of a circle?

12. How many degrees are in a quadrant of a circle?

13. How many degrees are in a semi-circle?

14. What term is given to the angle of a circle that is half of a right angle?

15. Give sketch and describe how three right angles may be formed within a semi-circle.

16. Give sketch and describe how a hexagon may be formed within a circle.

17. Give sketch of a hexagon showing how an equilateral triangle may be formed.

18. Give sketch and describe how a right angle or quadrant may be bisected.

19. Give sketch and describe how to get a straight line that shall equal the circumference of a circle or part of a circle or quadrant.

20. Give sketch and show how quadrant may be divided into any number of equal parts, say thirteen.

21. Give sketch and show how equilateral triangle may be employed in forming the trefoil.

22. Give sketch and describe method of finding the "stretch out" or length of circumference of a circle.

23. Give rule by arithmetic of how to find the circumference of a circle.

24. Give sketch and describe how a curve having

any reasonable radius, may be obtained, if but three points in the circumference are available.

25. Give a practical illustration of how to find a place to locate a center, where the diameter is great.

26. What is a "polygon?"

27. Give the names applied to polygons having three sides, four sides, five sides, six sides, seven sides, eight sides, nine sides, ten side, eleven sides, and twelve sides respectively.

28. Give the two names under which polygons are classified.

29. Give sketch showing how a trigon may be constructed and how the miter joint may be obtained.

30. Give sketch and describe how a square may be formed.

31. Give sketch and describe how to construct a pentagon.

32. Give sketch and describe how a hexagon may be formed.

33. Give sketch and describe how a heptagon may be formed.

34. Give sketch and describe how an octagon may be formed.

35. Show practically how all regular octagons may be constructed.

36. Give a practical illustration of how a perpendicular line may be made on any given straight line.

37. Give a practical illustration of how to bisect an angle by the aid of the steel square alone.

38. Give a practical illustration of how to bisect an acute angle by same method—steel square.

39. Show practically how to get a correct miter cut, or angle of 45° on a board.

40. Show how to construct a figure showing an angle of 30° on one side, and on the other an angle of 60°.

41. Show how the diameter of a circle may be obtained through the aid of the steel square.

42. Show how an equilateral triangle may be obtained through use of the steel square.

43. Show how to describe an octagon by using the steel square.

44. Show how a near approximation of the circumference of a circle may be obtained by use of the steel square and a straight line.

45. Give illustration how a board may be divided into any given number of equal parts by aid of steel square or pocket rule.

46. Give the definition of an "ellipse."

47. Give an illustration of one of the simplest methods of describing an ellipse.

48. Give an illustration of projecting an ellipse by using a trammel.

49. Give illustration of describing an ellipse by the intersection of lines.

50. Give illustration of describing an ellipse by the intersection of arcs.

51. Show how radial lines may be obtained for arches and elliptical work.

52. Give an illustration how to describe a diamond or lozenge-shaped figure.

53. Give illustration how to describe a spiral or scroll by a simple method.

54. Give illustration of how a spiral may be described in a scientific manner, and which can be formed to dimension.

55. Give illustration of the method of obtaining a spiral by arcs of circles.

56. Give illustration and method of forming a "parabola."

57. Give illustration and method of forming an "hyperbola."

58. Give the names of the different kinds of arches in buildings.

59. Mention the names given to pointed arches.

60. What is the name given to the stones forming an arch?

61. What is the name given to the centre stone in an arch?

62. Give the names applied to the various divisions of an arch, namely, the highest point, the lowest point, and the spaces between respectively.

63. What is the name given to the under or concave surface of an arch?

64. What is the name given to the upper or convex surface of an arch?

65. What are the names given to the supports of an arch?

66. Show by illustration and describe how to obtain the curves and radiating lines of a semi-circular arch.

67. Show by illustration and describe how to obtain the curves and radiating lines of a segment arch.

68. Show by illustration and describe two examples of Moorish or Saracenic arches, one of which is pointed.

69. What is a "flatband"?

70. Give illustration and describe how to obtain the curves and radiating lines of the elliptic arch.

71. Give illustration and describe how the centers and curves of an equilateral arch may be obtained.

72. Give illustration and describe how the centers and curves of a lancet arch may be obtained.

73. Give illustration and describe how the center and curves of a low or drop arch may be obtained.

74. Give illustration and describe how the centers and curves of a Gothic arch with a still less height, may be obtained.

75. Give illustration and describe another four-centered arch of less height.

76. Give illustration and describe how to obtain an equilateral Ogee arch.

77. Give illustration and describe method of obtaining the lines for an Ogee arch, having a height equal to half the span.

78. Give some instances in carpenter work where half of the Ogee curve is employed.

79. Give a description of the steel square and its several divisions.

80. Give a practical illustration of how a board or scantling may be measured by use of steel square.

81. Give rule how to find hypothenuse of a right-angled triangle.

82. Give an illustration of how length of braces may be obtained by use of the square.

83. Describe the use of the "octagonal scale" on the tongue of the square.

84. Show method how the pitch of a roof may be obtained by use of the square.

85. Show method to obtain bevels and lengths of hip rafters by use of the square.

86. Show method for finding the length and cuts for cross-bridging.

87. Show method for obtaining the "cuts" for octagon and hexagon joints.

88. Show by illustration the method of defining the pitches of roofs, and giving the figures on the square for laying out the rafters for such pitches.

89. Give a short description of what is known as balloon framing, and how the different parts are constructed.

90. Give illustration and describe a "hip-roof."

91. Give illustration and describe a "lean-to-roof."

92. Give illustration and describe a "saddle-roof."

93. Give illustration and describe a "mansard roof."

94. Give illustration and describe a simple hip-roof having a ridge.

95. Give illustration and describe an "octagon roof."

96. Give illustration and describe manner of construction of a "dome roof."

97. Give illustration and rules for construction of an octagonal spire.

98. Give a few illustrations of scarfing timbers.

99. Show a few examples of strengthening and trussing joints, girders and timbers.

100. Explain what is meant by the term "kerfing."

101. Give illustration showing how to determine the number and distances apart of saw kerfs required to bend a board round a corner.

102. Give illustration of how to make a "kerf" for bending round an ellipse.

103. Describe how to bend thick stuff around work that is on a rake.

104. Give illustration and describe how to lay out a hip rafter for a veranda having a curved roof.

105. Give illustration and describe how to obtain

the curve of a hip rafter, when the common rafters have an ogee or concave and convex shape.

106. Give illustration and describe how raking mouldings are used to work in level mouldings.

107. Describe the kind of mouldings called "spring mouldings."

108. Give illustrations showing plan and elevation of cluster column of wood for 4 columns and describe how constructed.

109. Give illustration of a hopper and describe how to be constructed.

110. Give illustration and describe how a conical tower roof may be curved.

111. Give illustration and describe how to cover a dome roof.

112. Give illustration and describe how the semicircular soffit of a doorway may be made.

113. Describe how a circle soffit may be laid off into panels.

114. Give illustration and describe method for obtaining correct shape of a veneer for a gothic-splayed window or door head.

115. Give illustrations and describe two methods of dovetailing hoppers, trays and other splayed work.

116. Give description of how an ordinary straight flight of stairs may be constructed.

117. Give sketch showing part of a straight stair.

118. Give sketch showing stair with winders and landing.

119. Give sketch and describe a stair with brackets.

120. Give sketch showing stair with two newels and balusters, also paneled string and spandrel.

121. Give sketches of seven of the latest designs for doors.

122. Give five sketches showing methods of constructing and finishing a window frame for weighted sash.

123. Give sketches showing the various parts of a bay window for a balloon frame.

124. Give illustration and describe six examples of shingling roofs.

125. Show by sketch how panels are formed.

126. Describe the various kinds of panels named.

127. Make sketch of a four-panel door.

128. How are air-tight cases made? Describe the method of making.

129. What is meant by the word "stile"?

130. What is a rail in a door? What is a muntin?

131. What is a chamfer? Describe one.

132. Examine examples of sketches of ornamental wood-work, draw and describe a "baye-board."

133. Make a design of perforated insular panel.

Table No. 4—Squares, Cubes, Square Roots, Cube Roots and Reciprocals of Numbers from 1 to 164.

No.	Square	Cube	Square Root	Cube Root	Reciprocal
1	1	1	1.00000	1.00000	1.00000
2	4	8	1.41421	1.25992	.50000
3	9	27	1.73205	1.44224	.33333
4	16	64	2.00000	1.58740	.25000
5	25	125	2.23606	1.70997	.20000
6	36	216	2.44948	1.81712	.16666
7	49	343	2.64575	1.91293	.14285
8	64	512	2.82842	2.00000	.12500
9	81	729	3.00000	2.08008	.11111
10	100	1000	3.16227	2.15443	.10000
11	121	1331	3.31662	2.22398	09090
12	144	1728	3.46410	2.28942	.08333
13	169	2197	3.60555	2.35133	.07692
14	196	2744	3.74165	2.41014	.07142
15	225	3375	3.87298	2.46621	.06666
16	256	4096	4.00000	2.51984	.06250
17	289	4913	4.12310	2.57128	.05882
18	324	5832	4.24264	2.62074	.05555
19	361	6859	4.35889	2.66840	.05263
20	400	8000	4.47213	2.71441	.05000
21	441	9621	4.58257	2.75892	.04761
22	484	10648	4.69041	2.80203	.04545
23	529	12167	4.79583	2.84386	.04347
24	576	13824	4.89897	2.88449	.04166
25	625	15625	5.00000	2.92401	.04000
26	676	17576	5.09901	2.96249	.03846
27	729	19683	5.19615	3.00000	.03703
28	784	21952	5.29150	3.03658	.03571
29	841	24389	5.38516	3.07231	.03448
30	900	27000	5.47722	3.10723	.03333
31	961	29791	5.56776	3.14138	.03225
32	1024	32768	5.65685	3.17480	.03125
33	1089	35937	5.74456	3.20753	.03030
34	1156	39304	5.83095	3.23961	.02941
35	1225	42875	5.91607	3.27106	.02857
36	1296	46656	6.00000	3.30192	.02777
37	1369	50653	6.08276	3.33222	.02702
38	1444	54872	6.16441	3.36197	.02631

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CHAPTER IV

SEVEN PROBLEMS FOR PRACTICE IN FRAMING ROOFS OF EQUAL PITCH

In the preceding chapters the terms used in roof-framing have been outlined and sections of roofs have been analyzed to demonstrate the application of the underlying fundamental principles involved. To make this instruction effective it must be coupled with practice. With this object in view and with the further idea of developing self confidence and increased performance in the use of the steel square and particularly in framing a roof, these problems are offered. They will serve as excellent exercises for individual practice and training and will greatly reduce the time usually spent in the industry acquiring similar information.

These plans are representative of the better class of roofs for residences; containing a variety of hips, valleys, jack, cripple and common rafters. In making layouts for these roofs some attention and thought should be given to designing. This is an important feature as many styles of roofs may be developed over the same plates. The architectural design should be considered, as the beauty of a residential section is dependent on the grace and pleasing appearance of its buildings. The buildings themselves may be laid out and equipped with all the conveniences at the command of an architect or owner and an ugly roof would overbalance all of these. The outer appearance of a build-

ing is the first thing that greets the eye of a prospective buyer and if he is not satisfied with the exterior it is doubtful if he will take the time and trouble to look at the interior.

The strength of the roof should be considered. It should be so framed as to carry its own weight without sagging and, especially in sections where heavy snow falls occur, it should be strong enough to resist the resulting weight.

Where possible all hips and valleys should have some tie with the ridge and plate and, although the entire length of a hip or valley rafter may not be used to give the desired outer effects of the roof, it will make a much stronger roof to run these timbers through, tying the walls together and making a more even distribution of the weights and strains likely to come upon the roof. Whether or not an attic is to be finished should be considered in designing a roof. More head room will be needed if the attic is to be finished than if it is to be left rough.

The general instructions given for laying out the previous problems should be followed in framing the following roofs. Make a working layout of each plan, full size, representing 1″ to the foot. It is suggested that the reader make models of the various roofs to the same scale as the layout. The figures on the plans are given in inches. To apply them full size read them as feet. Take the runs of the rafters from the layout. Develop the lengths with the steel square and fence. Number each rafter and ridge on the layout for ready identification and put the corresponding numbers on

the rafters as they are laid out. Lay off the position of each rafter on the plate and ridge, properly spaced. Lay out a profile of a common rafter on the layout for each different pitch roof so that the height of the plate level can be determined. Having done so, measure the distance from plancher level to the plate level and note the measurements in the specifications.

For the convenience of the framer a suitable distance is noted in the specifications preceding each problem. These measurements should be checked up and the method of determining the two levels should be thoroughly understood before proceeding. The specifications suggest suitable sizes of stock that can be used for practice framing without losing the practical application of any of the principles involved. The tables following each problem are intended only as a matter of information to give assurance to the framer that he has used the proper runs and determined the correct length of the rafters and they should be referred to only as a check upon his own work. The measurements listed are extreme lengths on the center lines. Make allowances where rafters intersect a ridge, hip or valley rafter.

In checking up a model built to a scale of 1″ to the foot, read the figures in the tables as inches. For example, on rafter No. 1 in the table following problem No. 1, the run would read 2″ and the length $2\frac{7\frac{1}{4}''}{12}$. The square being laid out in twelfths of an inch, it is an easy matter to check up the work accurately.

The projection, pitch, and width of facias in the

various problems differ to give variety and to stimulate interest. These figures can be further changed if desired, but the lengths in the accompanying tables will apply only to roofs for the particular pitch listed in the specifications preceding each problem. Should the pitch be changed, these lengths will change accordingly.

PROBLEM NO. 1

Specifications.—Plate 7/8″ x 2″.
Hip and valley rafters, 3/4″ x 1 1/4″.
Common and jack rafters, 3/8″ x 7/8″.
Ridge, 3/8″ x 1 1/8″.
Projection, 2″.
Facia, 5/8″.
Plancher level to plate level, 1 3/4″.
Pitch, 10″ rise in one foot (5/12 pitch).
Dimensions, see plan, Figure 20.
Rafters spaced 2″ on centers.

In framing a roof special attention should be given to the method of framing the rafters into each other. They should be framed so as to give solid nailing and strong bracing. Referring to the plan, Figure 20, the ridges, hips and valleys form the skeleton or backbone of the roof and carry most of the load. The jack, cripple and common rafters help to distribute the weight, but without a strong and rigid tie of the main rafters the roof would be weak and likely to collapse. Valleys *B* form a butt joint. Where two hips intersect a ridge, as hips *A* and ridge *G,* Figure 20, the ridge

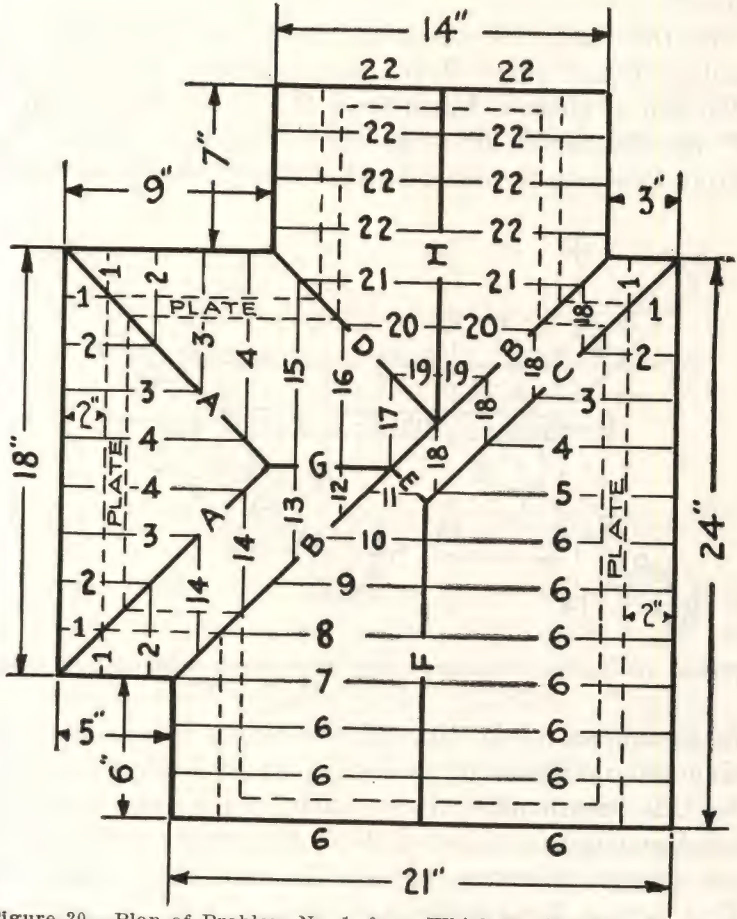


Figure 20.—Plan of Problem No. 1, from Which the Working Layout Is Made

should run between them. See enlarged section, Figure 21.

To Determine the Length of Ridge G.—Lay in hips *A*, valleys *B* and ridge *G*, full size as shown in Figure 21. The run of ridge *G* taken from the layout, Figure 20, is 5″ on the center lines as shown by *C-E*, Figure 21. From this length deduct one-half the thickness of valley

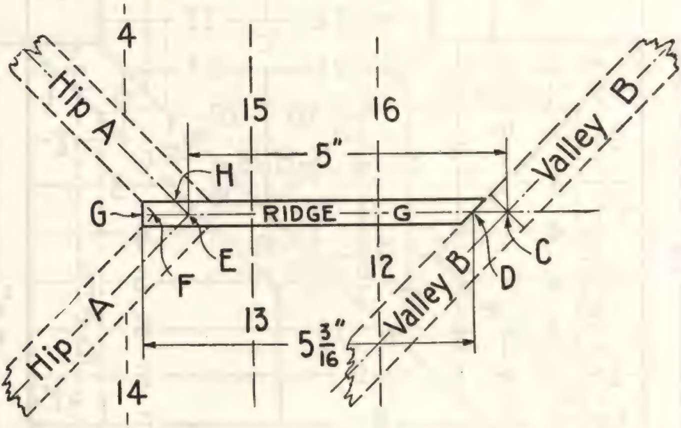


Figure 21.—Section Through Ridge G, Showing a Method of Determining the Length of the Ridge

B, measured on he line of the ridge, or one-half the diagonal thickness of valley *B*, as at *C-D*, Figure 21. To this length add on the other end of the ridge the same amount as deducted, *E-F*, Figure 21, and also add one-half the thickness of ridge *G*, as at *F-G*, Figure 21. This brings the outside end of the ridge in line with the short points of the bevel joint of hips *A* against ridge *G*.

If the reason for making these deductions and addi-

tions is clear, it will readily be seen that the length of the ridge is equal to the run plus one-half the thickness of the ridge *F-G*, or 5 3/16″, the measurements being taken on the center line. To make a fit against the side of valley *B* draw a miter, or angle of forty-five degrees, through the length on the center line on the top edge of the ridge.

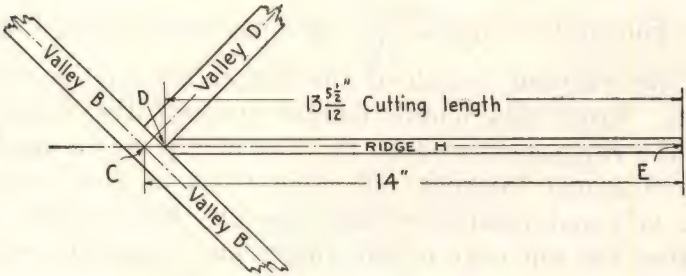


Figure 22.—Section Through Ridge *H*, Showing a Method for Determining the Length of the Ridge and for Fitting into the Intersection of Valleys *B* and *D*

To Determine the Length of Ridge H.—The run of ridge *H*, taken from the layout, Figure 20, is 14″ on the center lines as shown at *C-E*, Figure 22. From this length deduct one-half the thickness of valley *B* measured on the line of ridge *H*, or one-half the diagonal thickness of valley *B* as at *C-D*, Figure 22. To make a fit into the intersection of valleys *B* and *D* draw a miter or angle of forty-five degrees, right and left hand, through the length on the center line on the top edge of the ridge as shown in Figure 22.

To Lay Out Hips A.—Set the fence and square at 10″ rise on the tongue and 17″ run on the blade. Mark on the tongue for all plumb cuts and on the blade for

all level cuts. The run of hip A is taken from the layout, Figure 20, measuring from the return corner of the facia line to the center of ridge *G*, or $12\frac{8\frac{3}{4}''}{12}$. Press the fence firmly against the top edge of the stock to be used and produce the facia or first plumb line to the extreme left, *A*, Figure 23. Slide the fence to the right and measure on a level line from facia line *A* the run of the hip, $12\frac{8\frac{3}{4}''}{12}$, and produce line *C*, Figure 23, the extreme length of the hip rafter on the center line. From this length deduct one-half the thickness of the ridge measured on the line of hip *A*, or one-half the diagonal thickness of ridge *G* as at *E-H*, Figure 21, ¼″, and produce plumb line *D*. Square this line across the top edge of the rafter and locate the center point.

To lay out the top cut so that the hip rafter will fit against the side of the ridge measure forward on a level line from plumb line *D* a distance equal to one-half the thickness of the stock used for the hip, ⅜″, and produce plumb line *1*. Connect plumb line *1* through plumb line *D* on the top edge and produce bevel *2* as shown in the top view, Figure 23. This top cut can also be laid out with the steel square by using 9⅞″ (the bridge measure of one-half of the run 17″ and one-half the rise 10″) on the blade and 8½″ (one-half the run 17″) on the tongue. Mark on the blade for the top cut.

To complete the lower end of the rafter measure in on a level line from facia line *A* the diagonal distance

of the projection 2″ x 2″, or 2 10/12″, and produce wall line *B*. Measure down on facia line *A* from the top edge of the rafter 5/8″, the width of the facia, and produce plancher level *F*. Measure up from plancher level *F*, 1¾″, locating plate level *G*.

To make the return on the facia line at the corner of the building square facia line *A* across the top edge of

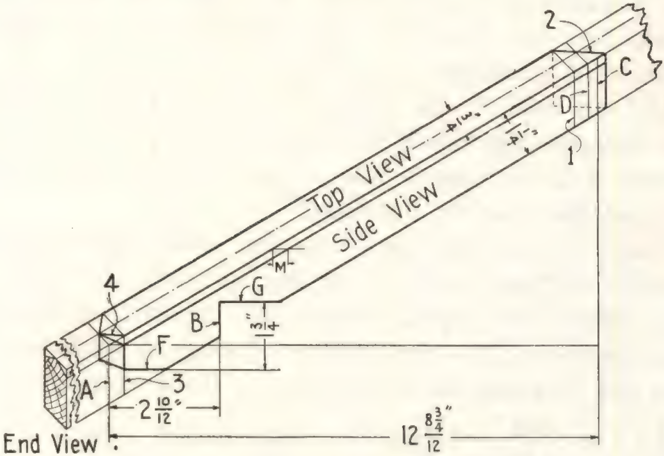


Figure 23.—Developed Length of Hip *A*

the rafter and locate the center point, measure in on a level line from facia line *A*, on either side of the rafter, a distance equal to one-half the thickness of the stock used for the hip, 3/8″, and produce plumb line *3*. Connect plumb line *3* with the center point on the facia line as shown at *4*, top view, Figure 23. This top cut is the same as the top cut at the upper end of the rafter, the same figures on the square giving the cut.

To determine the amount of backing so that the center

line of the hip will come in alignment with the top edges of the common and jack rafters, first gauge a line through the center of the rafter on the top edge. Then produce a level line anywhere on the side of the rafter. On this level line measure off a distance equal to one-half the thickness of the stock used, ⅜″, from the top edge as at *M*, Figure 23. Through this point gauge a line parallel to the top edge. Remove the corner of the stock between this line and the center line for the amount of backing.

Cut on line *A*, on bevels *4* for the facia, on line *F* for the plancher level, on lines *G* and *B* for the birds-mouth and on plumb line *1*, on bevel *2* for the joint against the side of the ridge.

To Lay Out Hip E.—Use the same figures on the square as those used in laying out hip *A*. Take the run from the layout, Figure 20, measuring from the intersection of the center lines of ridge *G* and valleys *B* and the intersection of the center lines of ridge *F* and hip *C*, or $2\frac{1\frac{1}{2}''}{12}$. Press the fence firmly against the top edge of the stock to be used for the hip and produce the first plumb line *A* to the extreme left, Figure 24. Slide the fence to the right and measure on a level line from plumb line *A* the run of the hip, $2\frac{1\frac{1}{2}''}{12}$, and produce plumb line *C*, the extreme length of the hip on the center lines. From the bottom end deduct one-half the thickness of valley *B*, or ⅜″, and produce plumb line *D*, which is a square butt joint against valley *B*, valley *B* and hip *E* intersecting at right angles. From

the top end deduct one-half the thickness of the ridge measured on the line of the hip rafter, or one-half the diagonal thickness of ridge *F*, ¼″, and produce plumb line *3*. Square this line across the top edge of the

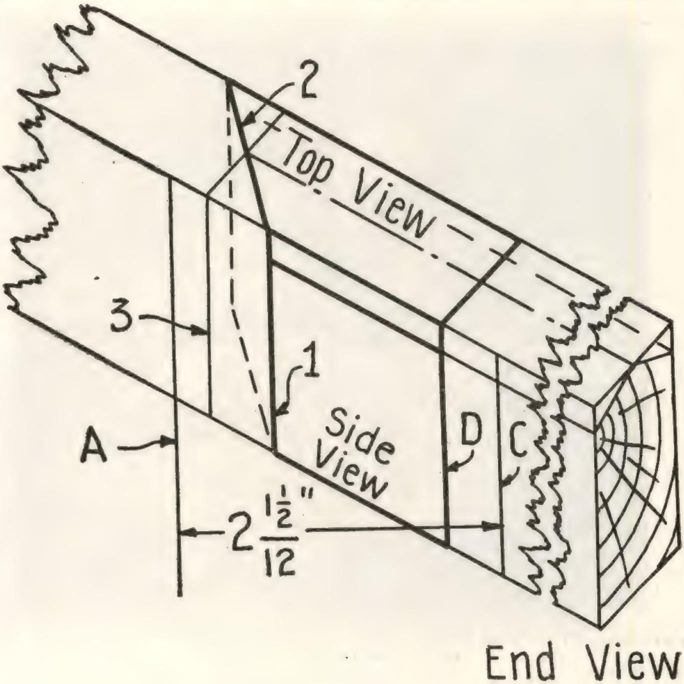


Figure 24.—Developed Length of Hip *E*

rafter and locate the center point.

To lay out the top cut so that the hip will fit against the ridge at the proper angle measure back on a level line from plumb line *3* a distance equal to one-half the thickness of the stock used for the hip, ⅜″, and pro-

duce plumb line *1*. Connect plumb line *1* through plumb line *3* on the top edge and produce bevel *2* as shown in the top view, Figure 24. This top cut can also be laid out with the steel square by using the same figures as those given for laying out the top cut for hips *A*.

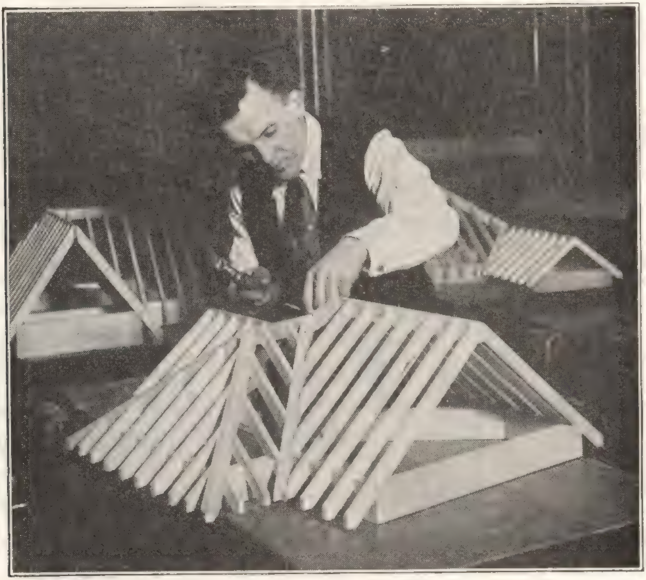


Figure 25.—Front and Right Side Elevation, Problem 1, Showing Method of Framing the Rafters

Back the hip rafter on either side according to the rules for backing described for backing hips *A*. Cut on line *D* for the butt joint against the side of valley *B* and on plumb line *1*, on bevel *2* for the cut against the side of ridge *F*.

This gives an outline of the method of developing the

length of the rafters and ridges which should enable the reader to complete the roof.

To Assemble the Roof.—Assemble the rafters as shown in the elevations, Figures 25 and 26. Set up valleys *B* first. Then valley *D* and ridge *H*, locating

Figure 26.—Rear and Left Side Elevation, Problem 1, Showing Method of Framing the Rafters

the proper height of ridge *H* with a pair of common rafters No. 22. Then set up hips *A*, ridge *G* and lastly hips *C* and *E* and ridge *F*, locating the proper height of ridge *F* with a pair of common rafters No. 6. Particular attention should be paid in fastening the rafters to keep

the center lines and top edges in alignment. Notice that the top edges of the ridges are not in alignment with the center lines of the hip and valley rafters but dropped to overcome the need for backing the ridges, the roof board continuing the lines of the roof to the extreme height.

RUNS AND LENGTHS OF RAFTERS USED IN FRAMING PROBLEM NO. 1—5/12 PITCH

Number of Rafters	Quantity of Rafters	Runs	Lengths	Kind of Rafters
1	3 pair	2′ 0″	2′ 7¼″	Jack Rafters
2	2 1/2 pair	4′ 0″	5′ 2½″	Jack Rafters
3	1 2/2 pair	6′ 0″	7′ 9¾″	Jack Rafters
4	1 2/2 pair	8′ 0″	10′ 5″	Jack Rafters
5	1	10′ 0″	13′ 0¼″	Jack Rafter
6	10	10′ 6″	13′ 8″	Common Rafters
7	1	10′ 6″	13′ 8″	Jack Rafter
8	1	8′ 6″	11′ 0¾″	Jack Rafter
9	1	6′ 6″	8′ 5½″	Jack Rafter
10	1	4′ 6″	5′10¼″	Jack Rafter
11	1	2′ 0″	2′ 7¼″	Cripple Rafter
12	1	2′ 0″	2′ 7¼″	Jack Rafter
13	1	4′ 0″	5′ 2½″	Jack Rafter
14	2	5′ 0″	6′ 6⅛″	Cripple Rafters
15	1	8′ 0″	10′ 5″	Jack Rafter
16	1	6′ 0″	7′ 9¾″	Jack Rafter
17	1	4′ 0″	5′ 2½″	Jack Rafter
18	4	3′ 0″	3′10⅞″	Cripple Rafters
19	1 pair	2′ 0″	2′ 7¼″	Jack Rafters
20	1 pair	4′ 0″	5′ 2½″	Jack Rafters
21	1 pair	6′ 0″	7′ 9¾″	Jack Rafters
22	8	7′ 0″	9′ 1⅜″	Common Rafters
A	1 pair	12′ 8¾″	14′ 9¼″	Hip Rafters
B	1 pair	12′ 8¾″	14′ 9¼″	Valley Rafters
C	1	14′10⅛″	17′ 2⅞″	Hip Rafter
D	1	9′10¾″	11′ 5⅞″	Valley Rafter
E	1	2′ 1½″	2′ 5½″	Hip Rafter
F	1	13′ 6″	13′ 6″	Ridge
G	1	5′ 0″	5′ 0″	Ridge
H	1	14′ 0″	14′ 0″	Ridge

Figures used on the steel square:

Common, jack and cripple rafters, 10″ on tongue, 12″ on blade. Mark on tongue for plumb cuts and on blade for level cuts.

Top cut for jack and cripple rafters, 12″ on tongue, 15⅝″ on blade. Mark on blade for top cut.

Hip and valley rafters, 10″ on tongue, 17″ on blade. Mark on tongue for plumb cuts and on blade for level cuts.

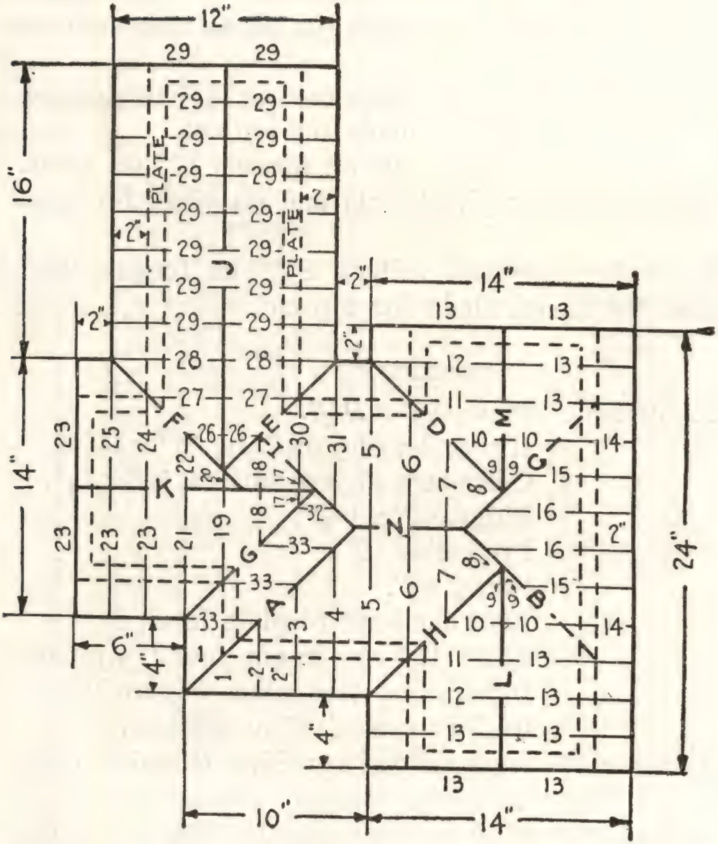
Top cut for hips and valleys, 8½″ on tongue, 9⅞″ on blade. Mark on blade for top cut.

PROBLEM NO. 2

Specifications.—Plate, ⅞″ x 2½″.
Hip and valley rafters, ¾″ x 1¼″.
Common and jack rafters, ⅜″ x ⅞″.
Ridge, ⅜″ x 1⅛″.
Projection, 2″.
Facia, ⅝″.
Plancher level to plate level, 2″.
Pitch, 12″ rise in one foot (½ pitch).
Dimensions (see plan, Figure 27).
Rafters spaced 2″ on centers.

In framing the main rafters run hips *B* and *C* from ridge *N* to the plate, giving support for valleys *D* and *H*. Run valley *F* from the facia line to ridge *K*, giving support for valley *E*.

Hip *B* should be backed the entire length on one side and from ridge *N* to the intersection of valley *H* on the other side. Hip *C* should be backed the entire length on



igure 27.—Plan of Problem No. 2, from Which the Working Layout Is Made

one side and from ridge *N* to the intersection of valley *D* on the other side. Hip *I* should be backed the entire length on one side and from ridge *N* to the intersection of valley *G* on the other side.

To Assemble the Roof.—Assemble the rafters as

Figure 28.—Front and Right Side Elevation, Problem 2, Showing the Method of Framing the Rafters

shown in the elevations, Figures 28 and 29. Set up ridge *N* first, supported by hips, *A, B* and *C*. Next set up valley *H* and ridge *L*, supported by a pair of *No. 13* common rafters. Then valley *D* and ridge *M* supported by a pair of No. *13* common rafters. Then hip *I*, valley

G and ridge *K*, supported by a pair of No. 23 common rafters. Lastly valleys *E* and *F* and ridge *J*, supported by a pair of No. 29 common rafters.

Figure 29.—Rear and Left Side Elevation, Problem 2, Showing the Method of Framing the Rafters

RUNS AND LENGTHS OF RAFTERS USED IN FRAMING PROBLEM NO. 2—½ PITCH

Number of Rafters	Quantity of Rafters	Runs	Lengths	Kind of Rafters
1	1 pair	2′ 0″	2′10″	Jack Rafters
2	1	4′ 0″	5′ 7⅞″	Jack Rafter
3	1	6′ 0″	8′ 5⅞″	Jack Rafter
4	1	8′ 0″	11′ 3¾″	Jack Rafter
5	1 pair	9′ 0″	12′ 8¾″	Jack Rafters
6	1 pair	7′ 0″	9′10¾″	Jack Rafters
7	1 pair	5′ 0″	7′ 0⅞″	Jack Rafters
8	2	2′ 0″	2′10″	Cripple Rafters

RUNS AND LENGTHS OF RAFTERS USED IN FRAMING PROBLEM NO. 2—½ PITCH—Continued

Number of Rafters	Quantity of Rafters	Runs	Lengths	Kind of Rafters
9	2 pair	1′ 0″	1′ 5″	Jack Rafters
10	2 pair	3′ 0″	4′ 2⅞″	Jack Rafters
11	1 pair	5′ 0″	7′ 0⅞″	Jack Rafters
12	1 pair	7′ 0″	9′10¾″	Jack Rafters
13	10	7′ 0″	9′10¾″	Common Rafters
14	1 pair	4′ 0″	5′ 7⅞″	Jack Rafters
15	1 pair	6′ 0″	8′ 5⅞″	Jack Rafters
16	1 pair	8′ 0″	11′ 3¾″	Jack Rafters
17	1 pair	1′ 0″	1′ 5″	Jack Rafters
18	1 pair	3′ 0″	4′ 2⅞″	Jack Rafters
19	1	5′ 0″	7′ 0⅞″	Jack Rafter
20	1	1′ 0″	1′ 5″	Jack Rafter
21	1	7′ 0″	9′10¾″	Jack Rafter
22	1	3′ 0″	4′ 2⅞″	Jack Rafter
23	4	7′ 0″	9′10¾″	Common Rafters
24	1	5′ 0″	7′ 0⅞″	Jack Rafter
25	1	7′ 0″	9′10¾″	Jack Rafter
26	1 pair	2′ 0″	2′10″	Jack Rafters
27	1 pair	4′ 0″	5′ 7⅞″	Jack Rafters
28	1 pair	6′ 0″	8′ 5⅞″	Jack Rafters
29	16	6′ 0″	8′ 5⅞″	Common Rafters
30	1	4′ 0″	5′ 7⅞″	Cripple Rafter
31	1	8′ 0″	11′ 3¾″	Cripple Rafter
32	1	2′ 0″	2′10″	Cripple Rafter
33	3	4′ 0″	5′ 7⅞″	Cripple Rafters
A	1	12′ 8¾″	15′ 7″	Hip Rafter
B	1	9′10¾″	12′ 1½″	Part Hip and Part Valley
C	1	9′10¾″	12′ 1½″	Part Hip and Part Valley
D	1	9′10¾″	12′ 1½″	Valley Rafter
E	1	8′ 5⅞″	10′ 4¾″	Valley Rafter
F	1	9′10¾″	12′ 1½″	Valley Rafter
G	1	9′10¾″	12′ 1½″	Valley Rafter
H	1	9′10¾″	12′ 1½″	Valley Rafter
I	1	7′ 0⅞″	8′ 7⅞″	Part Hip and Part Valley
J	1	22′ 0″	22′ 0″	Ridge
K	1	13′ 0″	13′ 0″	Ridge
L	1	11′ 0″	11′ 0″	Ridge
M	1	9′ 0″	9′ 0″	Ridge
N	1	6′ 0″	6′ 0″	Ridge

Figures used on the steel square:

Common, jack and cripple rafters, 12″ on tongue, 12″ on blade. Mark on tongue for plumb cuts and on blade for level cuts.

Top cut for jack and cripple rafters, 12″ on tongue, 17″ on blade. Mark on blade for top cut.

Hip and valley rafters, 12″ on tongue, 17″ on blade. Mark on tongue for plumb cuts and on blade for level cuts.

Top cut for hip and valley rafters, 8½″ on tongue, 10⅜″ on blade. Mark on blade for top cut.

PROBLEM NO. 3

Specifications.—Plate, ⅞″ x 2″.
Hip and valley rafters, ¾″ x 1¼″.
Common and jack rafters, ⅜″ x ⅞″.
Ridge, ⅜″ x 1⅛″.
Projection, 1½″.
Facia, ½″.
Plancher level to plate level, 1⅛″.
Pitch, 9″ rise in one foot (⅜ pitch).
Dimensions (see plan, Figure 30).
Rafters spaced 2″ on centers.

In framing the main rafters run hips *B* and *D* from ridge *H* to the plate, giving support for valleys *E* and *F*.

Hip *B* should be backed the entire length on one side and from ridge *H* to the intersection of valley *E* on

the other side. Hip *D* should be backed the entire length on one side and from ridge *H* to the intersection of valley *F* on the other side.

To Assemble the Roof.—Assemble the rafters as

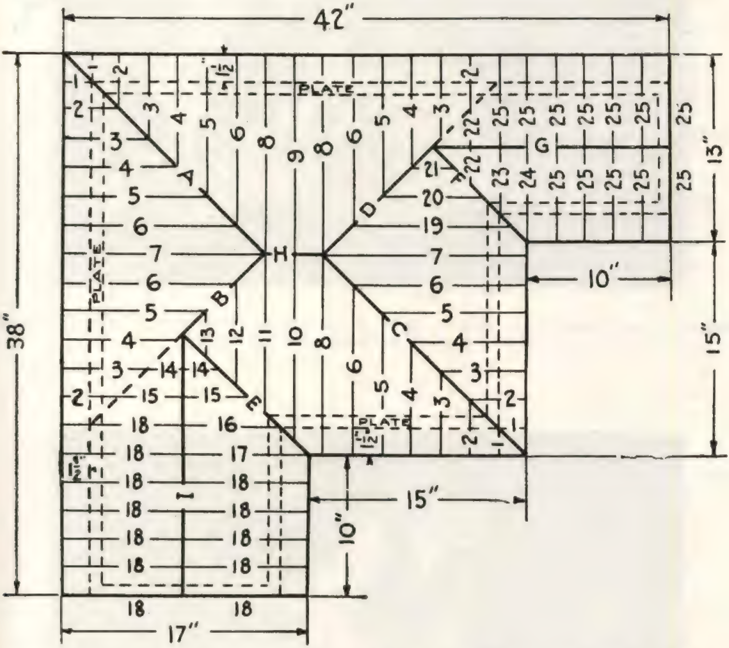


Figure 30.—Plan of Problem 3, from Which the Working Layout Is Made

shown in the elevations, Figures 31 and 32. Set up ridge *H* first, supported by hips *A*, *B*, *C* and *D*. Then valley *E* and ridge *I*, supported by a pair of No. 18 common rafters. Lastly valley *F* and ridge *G*, supported by a pair of No. 25 common rafters.

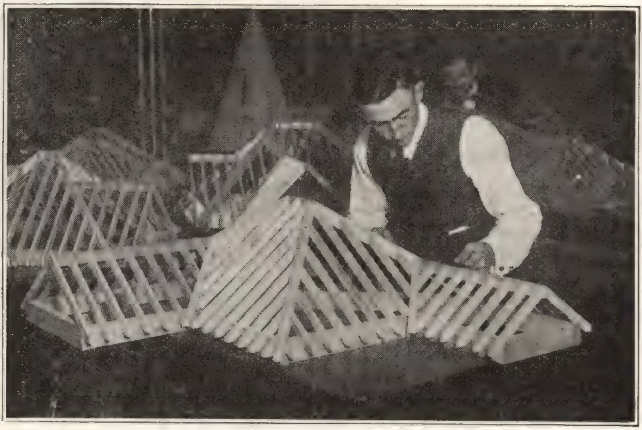


Figure 31.—Front and Right Side Elevation, Problem 3, Showing the Method of Framing the Rafters

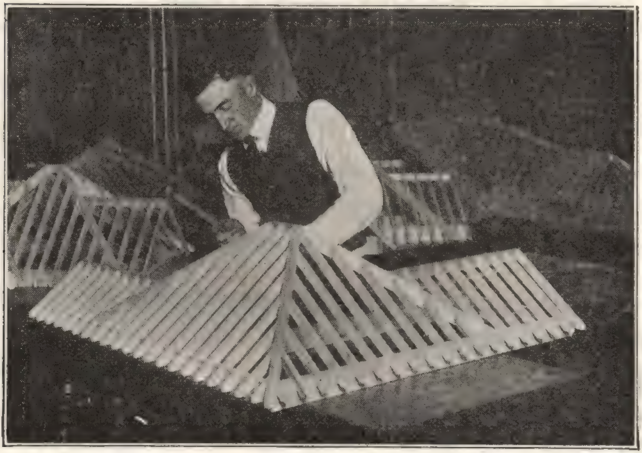


Figure 32.—Rear and Left Side Elevation, Problem 3, Showing the Method of Framing the Rafters

RUNS AND LENGTHS OF RAFTERS USED IN FRAMING PROBLEM NO. 3—3/8 PITCH

Number of Rafters	Quantity of Rafters	Runs	Lengths	Kind of Rafters
1	2 pair	2′0″	2′6″	Jack Rafters
2	3 pair	4′0″	5′0″	Jack Rafters
3	3 pair	6′0″	7′6″	Jack Rafters
4	3 pair	8′0″	10′0″	Jack Rafters
5	3 pair	10′0″	12′6″	Jack Rafters
6	3 pair	12′0″	15′0″	Jack Rafters
7	1 pair	14′0″	17′6″	Jack Rafters
8	1½ pair	14′0″	17′6″	Jack Rafters
9	1	14′0″	17′6″	Common Rafter
10	1	13′0″	16′3″	Jack Rafter
11	1	11′0″	13′9″	Cripple Rafter
12	1	7′0″	8′9″	Cripple Rafter
13	1	3′0″	3′9″	Cripple Rafter
14	1 pair	2′6″	3′1½″	Jack Rafters
15	1 pair	4′6″	5′7½″	Jack Rafters
16	1	6′6″	8′1½″	Jack Rafter
17	1	8′6″	10′7½″	Jack Rafter
18	12	8′6″	10′7½″	Common Rafters
19	1	11′0″	13′9″	Cripple Rafter
20	1	7′0″	8′9″	Cripple Rafter
21	1	3′0″	3′9″	Cripple Rafter
22	1 pair	2′6″	3′1½″	Jack Rafters
23	1	4′6″	5′7½″	Jack Rafter
24	1	6′6″	8′1½″	Jack Rafter
25	12	6′6″	8′1½″	Common Rafters
A	1	19′9⅝″	22′4⅞″	Hip Rafter
B	1	17′8⅛″	20′0⅛″	Part Hip and Part Valley
C	1	19′9⅝″	22′4⅞″	Hip Rafter
D	1	17′8⅛″	20′0⅛″	Part Hip and Part Valley
E	1	12′0¼″	13′7¼″	Valley Rafter
F	1	9′2¼″	10′4⅞″	Valley Rafter
G	1	16′6″	16′6″	Ridge
H	1	4′0″	4′0″	Ridge
I	1	18′6″	18′6″	Ridge

Figures used on the steel square:

Common, jack and cripple rafters, 9″ on tongue, 12″ on blade. Mark on tongue for plumb cuts and on blade for level cuts.

Top cut for jack and cripple rafters, 12″ on tongue, 15″ on blade. Mark on blade for top cut.

Hip and valley rafters, 9″ on tongue, 17″ on blade.

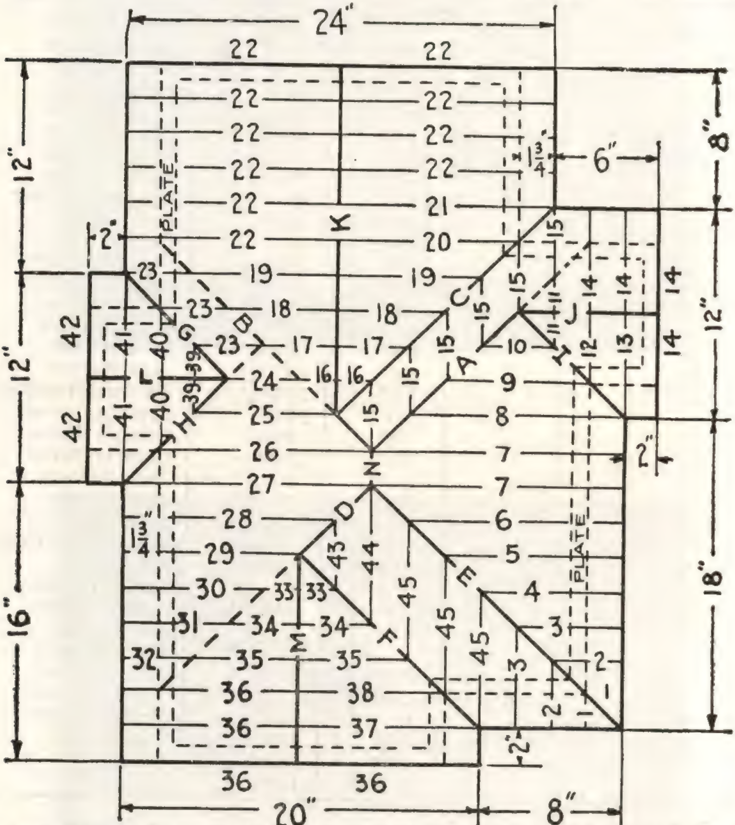


Figure 33.—Plan of Problem 4, from Which the Working Layout Is Made.

Mark on tongue for plumb cuts; on blade for level cuts.

Top cut for hip and valley rafters, $8\frac{1}{2}$″ on tongue, $9\frac{5}{8}$″ on blade. Mark on blade for top cut.

PROBLEM NO. 4

Specifications.—Plate, 7/8″ x 2″.
Hip and valley rafters, 3/4″ x 1 1/4″.
Common and jack rafters, 3/8″ x 7/8″.
Ridge, 3/8″ x 1 1/8″.
Projection, 1 3/4″.
Facia, 5/8″.
Plancher level to plate level, 1 5/8″.
Pitch, 11″ rise in one foot (11/24 pitch).
Dimensions (see plan, Figure 33).
Rafters spaced 2″ on centers.

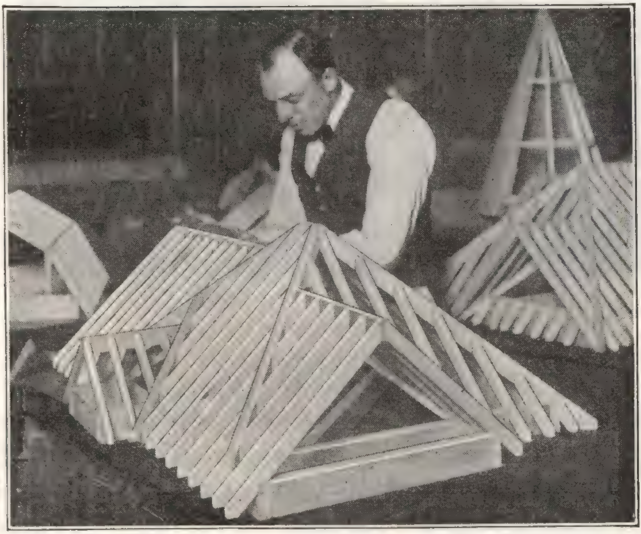


Figure 34.—Front and Right Side Elevation, Problem 4, Showing the Method of Framing the Rafters

In framing the main rafters run hips *A*, *B* and *D* from ridge *N* to the plate and hip *E* from ridge *N* to the facia line, giving support for valleys *C*, *F*, *H* and *I*. Run valley *H* from the facia line to hip *B*, giving support for valley *G*.

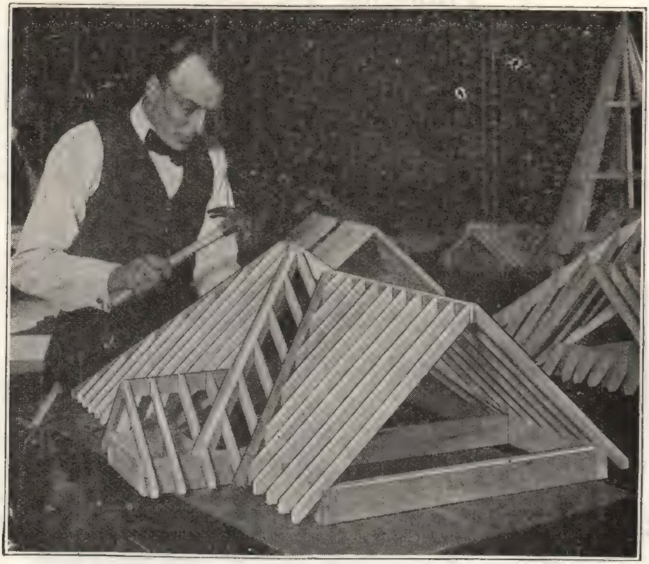


Figure 35.—Rear and Left Side Elevation, Problem 4, Showing the Method of Framing the Rafters

Hip rafter *B* should be backed the entire length on one side and the backing stopped at the intersection of ridge *K* on the other side, beginning at ridge *N*. Hip rafter *A* should be backed the entire length on one side and on the other side the backing should begin at ridge *N* and stop at the intersection of valley *I*. Hip rafter *D* should be backed the entire length on one side and on

the other side the backing should begin at ridge *N* and stop at the intersection of valley *F*.

To Assemble the Roof.—Assemble the rafters as shown in the elevations, Figures 34 and 35. Set up ridge *N* first, supported by hips *A*, *B*, *D* and *E*. Then valley *C* and ridge *K*, supported by a pair of No. 22 common rafters. Then valleys *H* and *G* and ridge *L* supported by a pair of No. 42 common rafters. Then valley *I* and ridge *J*, supported by a pair of No. 14 common rafters. Lastly valley *F* and ridge *M*, supported by a pair of No. 36 common rafters.

RUNS AND LENGTHS OF RAFTERS USED IN FRAMING PROBLEM NO. 4—11/24 PITCH

Number of Rafters	Quantity of Rafters	Runs	Lengths	Kind of Rafters
1	1 pair	2′ 0″	2′ 8½″	Jack Rafters
2	1 pair	4′ 0″	5′ 5⅛″	Jack Rafters
3	1 pair	6′ 0″	8′ 1⅝″	Jack Rafters
4	1	8′ 0″	10′10¼″	Jack Rafter
5	1	10′ 0″	13′ 6¾″	Jack Rafter
6	1	12′ 0″	16′ 3⅜″	Jack Rafters
7	2	14′ 0″	18′11⅞″	Jack Rafters
8	1	12′ 0″	16′ 3⅜″	Cripple Rafter
9	1	8′ 0″	10′10¼″	Cripple Rafter
10	1	4′ 0″	5′ 5⅛″	Cripple Rafter
11	1 pair	2′ 0″	2′ 8½″	Jack Rafters
12	1	4′ 0″	5′ 5⅛″	Jack Rafter
13	1	6′ 0″	8′ 1⅝″	Jack Rafter
14	4	6′ 0″	8′ 1⅝″	Common Rafters
15	6	4′ 0″	5′ 5⅛″	Cripple Rafters
16	1 pair	2′ 0″	2′ 8½″	Jack Rafters
17	1 pair	4′ 0″	5′ 5⅛″	Jack Rafters
18	1 pair	6′ 0″	8′ 1⅝″	Jack Rafters
19	1 pair	8′ 0″	10′10¼″	Jack Rafters
20	1	10′ 0″	13′ 6¾″	Jack Rafter
21	1	12′ 0″	16′ 3⅜″	Jack Rafter
22	10	12′ 0″	16′ 3⅜″	Common Rafters
23	3	4′ 0″	5′ 5⅛″	Cripple Rafters
24	1	4′ 0″	5′ 5⅛″	Cripple Rafter
25	1	8′ 0″	10′10¼″	Cripple Rafter

RUNS AND LENGTHS OF RAFTERS USED IN FRAMING PROBLEM NO. 4—11/24 PITCH—Continued

Number of Rafters	Quantity of Rafters	Runs	Lengths	Kind of Rafters
26	1	12′ 0″	16′ 3⅜″	Cripple Rafter
27	1	14′ 0″	18′11⅞″	Jack Rafter
28	1	12′ 0″	16′ 3⅜″	Jack Rafter
29	1	10′ 0″	13′ 6¾″	Jack Rafter
30	1	8′ 0″	10′10¼″	Jack Rafter
31	1	6′ 0″	8′ 1⅝″	Jack Rafter
32	1	4′ 0″	5′ 5⅛″	Jack Rafter
33	1 pair	2′ 0″	2′ 8½″	Jack Rafters
34	1 pair	4′ 0″	5′ 5⅛″	Jack Rafters
35	1 pair	6′ 0″	8′ 1⅝″	Jack Rafters
36	4	10′ 0″	13′ 6¾″	Common Rafters
37	1	10′ 0″	13′ 6¾″	Jack Rafter
38	1	8′ 0″	10′10¼″	Jack Rafter
39	1 pair	2′ 0″	2′ 8½″	Jack Rafters
40	1 pair	4′ 0″	5′ 5⅛″	Jack Rafters
41	1 pair	6′ 0″	8′ 1⅝″	Jack Rafters
42	2	6′ 0″	8′ 1⅝″	Common Rafters
43	1	4′ 0″	5′ 5⅛″	Jack Rafter
44	1	8′ 0″	10′10¼″	Jack Rafter
45	3	8′ 0″	10′10¼″	Cripple Rafters
A	1	17′ 3⅞″	20′ 7¾″	Part Hip and Part Valley
B	1	17′ 3⅞″	20′ 7¾″	Part Hip and Part Valley
C	1	16′11⅝″	20′ 2¾″	Valley Rafter
D	1	17′ 3⅞″	20′ 7¾″	Part Hip and Part Valley
E	1	19′ 9⅝″	23′ 7⅛″	Hip Rafter
F	1	14′ 1¾″	16′10¼″	Valley Rafter
G	1	8′ 5⅞″	10′ 1⅜″	Valley Rafter
H	1	11′ 3¾″	13′ 5¾″	Part Hip and Part Valley
I	1	8′ 5⅞″	10′ 1⅜″	Valley Rafter
J	1	8′ 0″	8′ 0″	Ridge
K	1	20′ 0″	20′ 0″	Ridge
L	1	8′ 0″	8′ 0″	Ridge
M	1	12′ 0″	12′ 0″	Ridge
N	1	2′ 0″	2′ 0″	Ridge

Figures used on the steel square:

Common, jack and cripple rafters, 11″ on tongue, 12″ on blade. Mark on tongue for plumb cuts and on blade for level cuts.

Top cut for jack and cripple rafters, 12″ on tongue, 16¼″ on blade. Mark on blade for top cut.

Hip and valley rafters, 11″ on tongue, 17″ on blade. Mark on tongue for plumb cuts and on blade for level cuts.

Top cut for hip and valley rafters, 8½″ on tongue and 10⅛″ on blade. Mark on blade for top cut.

PROBLEM NO. 5

Specifications.—Plate, ⅞″ x 2″.
Hip and valley rafters, ¾″ x 1¼″.
Common and jack rafters, ⅜″ x ⅞″.
Ridge, ⅜″ x 1⅛″.
Projection, 2″.
Facia, ⅝″.
Plancher level to plate level, 1¾″.
Pitch 10″ rise in one foot (5/12 pitch).
Dimensions (see plan, Figure 36).
Rafters spaced 2″ on centers.

In framing the main rafters run hip *B* from the facia line to ridge *I*, giving support for valley *H*. Run hips *C* from ridge *K* to the wall line, giving support for valleys *E* and *G*. Run ridge *K* from the intersection of hips *C* to hip *A*, giving support for valley *D* and hip *F*.

Hip *B* should be backed the entire length on one side and from ridge *I* to the intersection of valley *H* on the other side. One hip rafter marked *C* should be backed the entire length on one side and from ridge *K* to the

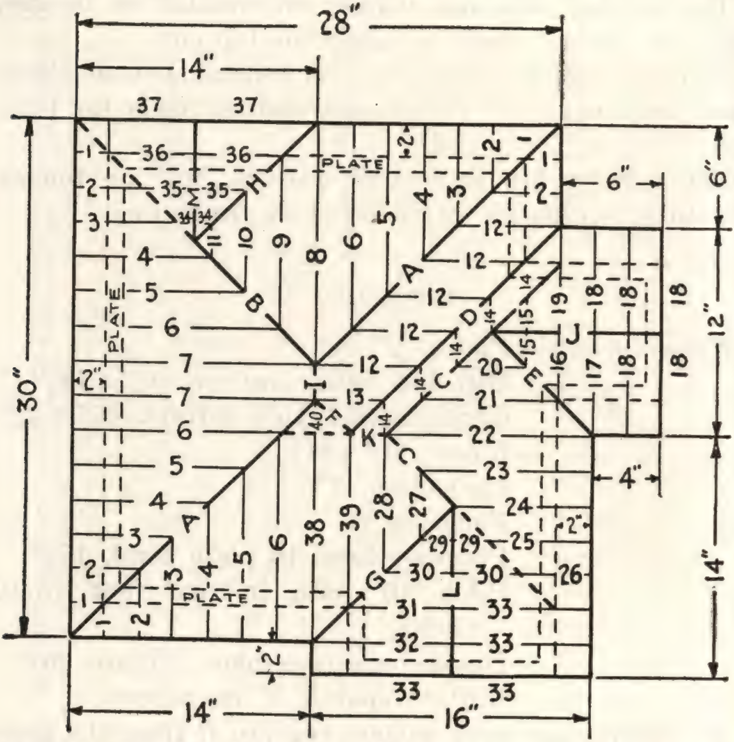


Figure 36.—Plan of Problem 5, from Which the Working Layout Is Made

intersection of valley *E* on the other side. The other hip marked *C* should be backed the entire length on one side and from ridge *K* to the intersection of valley *G* on the other side.

To Assemble the Roof.—Assemble the rafters as shown in the elevations, Figures 37 and 38. Set up ridge *I* first, supported by hips *A* and *B*. Then ridge *K*, supported by hips *C*. Then valley *D* and hip *F*.

Figure 37.—Front and Right Side Elevation, Problem 5, Showing the Method of Framing the Rafters

Then valley *E* and ridge *J*, supported by a pair of No. 18 common rafters. Then valley *G* and ridge *L*, supported by a pair of No. 33 common rafters. Lastly valley *H* and ridge *M*, supported by a pair of No. 37 common rafters.

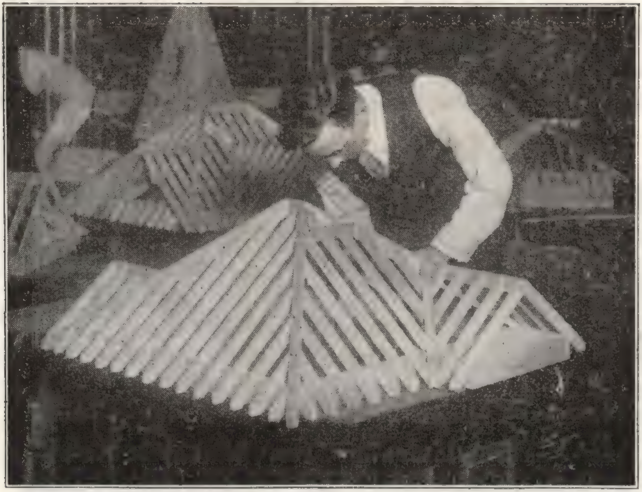


Figure 38.—Rear and Left Side Elevation, Problem 5, Showing the Method of Framing the Rafters

RUNS AND LENGTHS OF RAFTERS USED IN FRAMING PROBLEM NO. 5—5/12 PITCH

Number of Rafters	Quantity of Rafters	Runs	Lengths	Kind of Rafters
1	2 1/2 pair	2′ 0″	2′ 7¼″	Jack Rafters
2	2 1/2 pair	4′ 0″	5′ 2½″	Jack Rafters
3	1 2/2 pair	6′ 0″	7′ 9¾″	Jack Rafters
4	1 2/2 pair	8′ 0″	10′ 5″	Jack Rafters
5	1 2/2 pair	10′ 0″	13′ 0¼″	Jack Rafters
6	1 2/2 pair	12′ 0″	15′ 7½″	Jack Rafters
7	2	14′ 0″	18′ 2⅝″	Jack Rafters
8	1	14′ 0″	18′ 2⅝″	Cripple Rafter
9	1	10′ 0″	13′ 0¼″	Cripple Rafter
10	1	6′ 0″	7′ 9¾″	Cripple Rafter
11	1	2′ 0″	2′ 7¼″	Cripple Rafter
12	5	6′ 0″	7′ 9¾″	Cripple Rafters
13	1	4′ 0″	5′ 2½″	Cripple Rafter
14	5	2′ 0″	2′ 7¼″	Cripple Rafters
15	1 pair	2′ 0″	2′ 7¼″	Jack Rafters
16	1	4′ 0″	5′ 2½″	Jack Rafter
17	1	6′ 0″	7′ 9¾″	Jack Rafter
18	5	6′ 0″	7′ 9¾″	Common Rafters

RUNS AND LENGTHS OF RAFTERS USED IN FRAMING PROBLEM NO. 5—5/12 PITCH—Continued

Number of Rafters	Quantity of Rafters	Runs	Lengths	Kind of Rafters
19	1	6′ 0″	7′ 9¾″	Jack Rafter
20	1	4′ 0″	5′ 2½″	Cripple Rafter
21	1	8′ 0″	10′ 5″	Cripple Rafter
22	1	12′ 0″	15′ 7½″	Cripple Rafter
23	1	10′ 0″	13′ 0¼″	Jack Rafter
24	1	8′ 0″	10′ 5″	Jack Rafter
25	1	6′ 0″	7′ 9¾″	Jack Rafter
26	1	4′ 0″	5′ 2½″	Jack Rafter
27	1	4′ 0″	5′ 2½″	Cripple Rafter
28	1	8′ 0″	10′ 5″	Cripple Rafter
29	1 pair	2′ 0″	2′ 7¼″	Jack Rafters
30	1 pair	4′ 0″	5′ 2½″	Jack Rafters
31	1	6′ 0″	7′ 9¾″	Jack Rafter
32	1	8′ 0″	10′ 5″	Jack Rafter
33	4	8′ 0″	10′ 5″	Common Rafters
34	1 pair	1′ 0″	1′ 3⅝″	Jack Rafters
35	1 pair	3′ 0″	3′10⅞″	Jack Rafters
36	1 pair	5′ 0″	6′ 6⅛″	Jack Rafters
37	1 pair	7′ 0″	9′ 1⅜″	Jack Rafters
38	1	12′ 0″	15′ 7¼″	Jack Rafter
39	1	10′ 0″	13′ 0¼″	Jack Rafter
40	1	2′ 0″	2′ 7¼″	Jack Rafter
A	1 pair	19′9⅝″	22′11¾″	Hip Rafters
B	1	19′9⅝″	22′11¾″	Part Hip and part Valley
C	1 pair	14′1¾″	16′ 5″	Part Hip and Part Valley
D	1	16′11⅝″	19′ 8⅜″	Valley Rafter
E	1	8′5⅞″	9′ 10¼″	Valley Rafter
F	1	2′ 10″	3′ 3⅜″	Hip Rafter
G	1	11′3¾″	13′ 1⅝″	Valley Rafter
H	1	9′10¾″	11′ 5⅞″	Valley Rafter
I	1	2′ 0″	2′ 0″	Ridge
J	1	10′ 0″	10′ 0″	Ridge
K	1	6′ 0″	6′ 0″	Ridge
L	1	10′ 0″	10′ 0″	Ridge
M	1	7′ 0″	7′ 0″	Ridge

Figures used on the steel square:

Common, jack and cripple rafters, 10″ on tongue, 12″ on blade. Mark on tongue for all plumb cuts and on blade for all level cuts.

Top cut for jack and cripple rafters, 12″ on tongue, $15\frac{5}{8}$″ on blade. Mark on blade for top cut.

Hip and valley rafters, 10″ on tongue, 17″ on blade. Mark on tongue for all plumb cuts and on blade for all level cuts.

Top cut for hip and valley rafters, $8\frac{1}{2}$″ on tongue, $9\frac{7}{8}$″ on blade. Mark on blade for top cut.

PROBLEM NO. 6

Specifications.—Plate, $\frac{7}{8}$″ x $2\frac{1}{2}$″.
Hip and valley rafters, $\frac{3}{4}$″ x $1\frac{1}{4}$″.
Common and jack rafters, $\frac{3}{8}$″ x $\frac{7}{8}$″.
Ridge, $\frac{3}{8}$″ x $1\frac{1}{8}$″.
Projection: main roof, 2″; dormer, 1″.
Facia: main roof, $\frac{5}{8}$″; dormer, $\frac{1}{2}$″.
Plancher level to plate level: main roof, 2″; dormer, 1″.
Pitch, 12″ rise in one foot ($\frac{1}{2}$ pitch).
Dimensions (see plan, Figure 39).
Rafters spaced 2″ on centers.

In framing the main rafters run hip *B* from ridge *L* to the facia line, giving support for valleys *C* and *E*. Run valley *E* from hip *B* to the facia line, giving support for valley *D*. Run valley *F* from ridge *L* to the wall line, giving support for valley *G* and ridge *O*. Run valley *H* from ridge *Q* to valley *G*, giving support to valley *J*, hip *K* and valley *H*. Run valley *H* from the wall line by ridge *Q*, giving support for the dormer formed by valley *I* and ridge *P*.

Hip *B* should be backed the entire length on one

side and from ridge *L* to the intersection of valley *C* on the other side. Hip *F* should be backed the entire length on one side and from ridge *L* to the intersection of valley *G* on the other side.

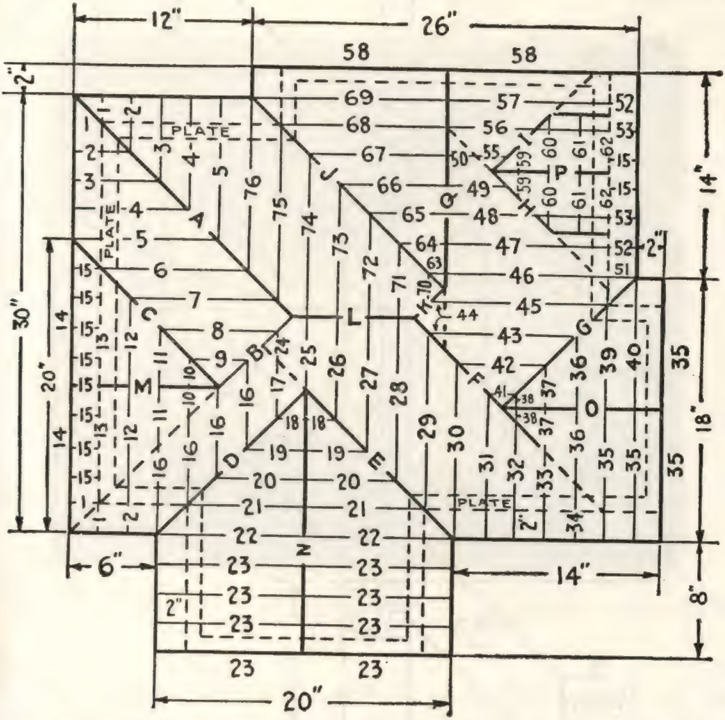


Figure 39.—Plan of Problem 6, from Which the Working Layout Is Made

A section through the dormer is shown in Figure 40. This shows a method for determining the height of the dormer plate above the main plate of the building. The dormer is formed by the intersection of valleys *H* and *I*.

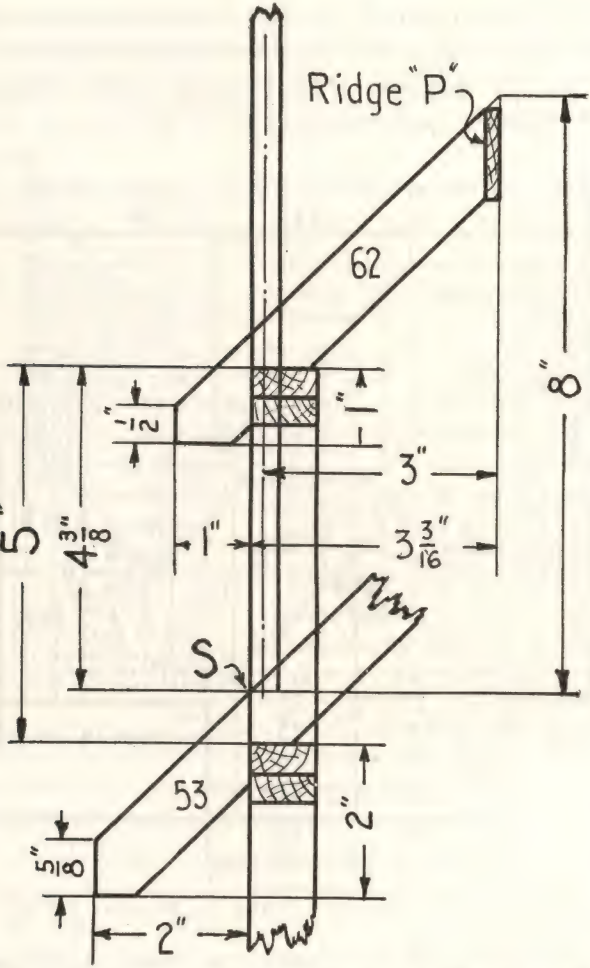


Figure 40.—Section Through Dormer, Problem 6, Showing a Method of Determining the Height of the Dormer Plate Above the Main Plate of the Building

The outside walls of the dormer are built up on the top of jack rafters No. 52 and No. 53, which makes the run of dormer common rafters No. 62, 3 3/16″ plus the projection, 1″, or a total run of 4 3/16″. Draw a profile of dormer common rafter No. 62 as shown in Figure 40

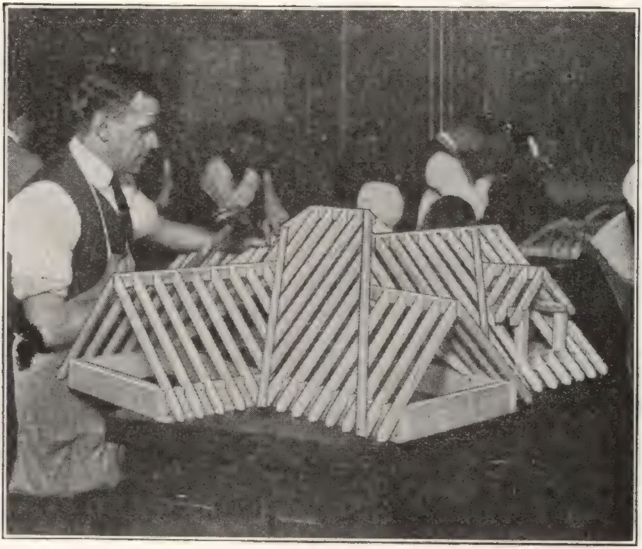


Figure 41.—Front and Right Side Elevation, Problem 6, Showing the Method of Framing the Rafters

and determine the plate level and birdsmouth in accordance with the requirements of the specifications. Draw the center line of ridge *P* and from the intersection of valleys *H*, *I* and ridge *P* mark off the run of the ridge, 8″, and produce the wall line. Through the point of intersection of the two wall lines as at *S*, Figure 40, draw in the top edge of common rafter No. 53 and

develop the plate level and birdsmouth of the main rafters in accordance with the requirements of the specifications. Measure out from wall line *B*, 2″, the width of the projection, and produce facia line *A*. Measure down on facia line *A* from the top edge of the rafter 5/8″, and produce plancher level *F*. Measure up

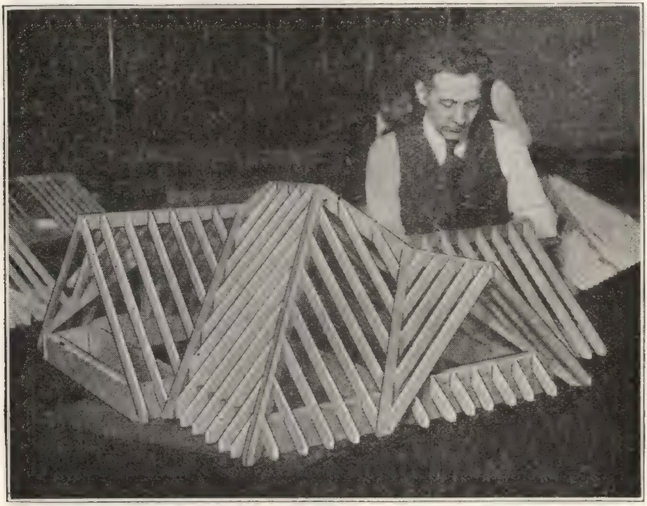


Figure 42.—Rear and Left Side Elevation, Problem 6, Showing the Method of Framing the Rafters

from plancher *F*, measuring on a plumb line, 2″, locating plate level *G*. The distance from the main plate level to the top of the dormer plate, or 5″, gives the height of the dormer plate above the main plate of the building. If the studding is placed on the top edge of common rafter No. 53 the height of the plate above the top edge of the rafter will be 4 3/8″.

To Assemble the Roof.—Assemble the rafters as shown in the elevations, Figures 41 and 42. Set up ridge *L* first, supported by hips *A, B* and *F*. Then valley *G* and ridge *O,* supported by a pair of No. 35 common rafters. Then ridge *Q,* supported by a pair of No. 58 common rafters. Then valley *J* and hip *K*. Then valleys *H* and *I*. Build up the dormer plate and then ridge *P,* supported by a pair of dormer common rafters No. 62. Then set up valleys *E* and *D* and ridge *N,* supported by a pair of common rafters No. 23. Lastly set up valley *C* and ridge *M,* supported by a pair of common rafters No. 14.

RUNS AND LENGTHS OF RAFTERS USED IN FRAMING PROBLEM NO. 6—½ PITCH

Number of Rafters	Quantity of Rafters	Runs	Lengths	Kind of Rafters
1	2 pair	2′ 0″	2′10″	Jack Rafters
2	1½ pair	4′ 0″	5′ 7⅞″	Jack Rafters
3	1 pair	6′ 0″	8′ 5⅞″	Jack Rafters
4	1 pair	8′ 0″	11′ 3¾″	Jack Rafters
5	1 pair	10′ 0″	14′ 1¾″	Cripple Rafters
6	1	10′ 0″	14′ 1¾″	Cripple Rafter
7	1	10′ 0″	14′ 1¾″	Cripple Rafter
8	1	8′ 0″	11′ 3¾″	Cripple Rafter
9	1	4′ 0″	5′ 7⅞″	Cripple Rafter
10	1 pair	2′ 0″	2′10″	Jack Rafters
11	1 pair	4′ 0″	5′ 7⅞″	Jack Rafters
12	1 pair	6′ 0″	8′ 5⅞″	Jack Rafters
13	1 pair	8′ 0″	11′ 3¾″	Jack Rafters
14	1 pair	10′ 0″	14′ 1¾″	Jack Rafters
15	10	2′ 0″	2′10″	Jack Rafters
16	1	6′ 0″	8′ 5⅞″	Cripple Rafter
17	1	4′ 0″	5′ 7⅞″	Cripple Rafter
18	1 pair	2′ 0″	2′10″	Jack Rafters
19	1 pair	4′ 0″	5′ 7⅞″	Jack Rafters
20	1 pair	6′ 0″	8′ 5⅞″	Jack Rafters
21	1 pair	8′ 0″	11′ 3¾″	Jack Rafters
22	1 pair	10′ 0″	14′ 1¾″	Jack Rafters

RUNS AND LENGTHS OF RAFTERS USED IN FRAMING PROBLEM NO. 6—½ PITCH—Continued

Number of Rafters	Quantity of Rafters	Runs	Lengths	Kind of Rafters
23	8	10′ 0″	14′ 1¾″	Common Rafters
24	1	2′ 0″	2′10″	Cripple Rafter
25	1	5′ 0″	7′ 0⅞″	Jack Rafter
26	1	7′ 0″	9′10¾″	Jack Rafter
27	1	9′ 0″	12′ 8¾″	Jack Rafter
28	1	11′ 0″	15′ 6⅝″	Jack Rafter
29	1	12′ 0″	16′11⅝″	Cripple Rafter
30	1	12′ 0″	16′11⅝″	Cripple Rafter
31	1	10′ 0″	14′ 1¾″	Jack Rafter
32	1	8′ 0″	11′ 3¾″	Jack Rafter
33	1	6′ 0″	8′ 5⅞″	Jack Rafter
34	1	4′ 0″	5′ 7⅞″	Jack Rafter
35	3	9′ 0″	12′ 8¾″	Common Rafters
36	1 pair	5′ 0″	7′ 0⅞″	Jack Rafters
37	1 pair	3′ 0″	4′ 2⅞″	Jack Rafters
38	1 pair	1′ 0″	1′ 5″	Jack Rafters
39	1	7′ 0″	9′10¾″	Jack Rafter
40	1	9′ 0″	12′ 8¾″	Jack Rafter
41	1	2′ 0″	2′10″	Cripple Rafter
42	1	6′ 0″	8′ 5⅞″	Cripple Rafter
43	1	9′ 0″	12′ 8¾″	Jack Rafter
44	1 pair	1′ 0″	1′ 5″	Cripple Rafters
45	1	11′ 0″	15′ 6⅝″	Jack Rafter
46	1	10′ 0″	14′ 1¾″	Jack Rafter
47	1	8′ 0″	11′ 3¾″	Jack Rafter
48	1	6′ 0″	8′ 5⅞″	Jack Rafter
49	1	4′ 0″	5′ 7⅞″	Jack Rafter
50	1	2′ 0″	2′10″	Jack Rafter
51	1	3′ 0″	4′ 2⅞″	Jack Rafter
52	1 pair	5′ 0″	7′ 0⅞″	Jack Rafter
53	1 pair	7′ 0″	9′10¾″	Jack Rafter
55	1	2′ 0″	2′10″	Cripple Rafter
56	1	6′ 0″	8′ 5⅞″	Jack Rafter
57	1	8′ 0″	11′ 3¾″	Jack Rafter
58	2 pair	13′ 0″	18′ 4⅝″	Common Rafters
59	1 pair	2′ 0″	2′10″	Jack Rafters Dormer
60	1 pair	4′ 0″	5′ 7⅞″	Jack Rafters Dormer
61	2	4′ 2¼″	5′11″	Common Rafters Dormer
62	2	4′ 2¼″	5′11″	Common Rafters Dormer

RUNS AND LENGTHS OF RAFTERS USED IN FRAMING PROBLEM NO. 6—½ PITCH—Continued

Number of Rafters	Quantity of Rafters	Runs	Lengths	Kind of Rafters
63	1	1′ 0″	1′ 5″	Jack Rafter
64	1	3′ 0″	4′ 2⅞″	Jack Rafter
65	1	5′ 0″	7′ 0⅞″	Jack Rafter
66	1	7′ 0″	9′10¾″	Jack Rafter
67	1	9′ 0″	12′ 8¾″	Jack Rafter
68	1	11′ 0″	15′ 6⅝″	Jack Rafter
69	1	13′ 0″	18′ 4⅝″	Jack Rafter
70	1	2′ 0″	2′10″	Cripple Rafter
71	1	5′ 0″	7′ 0⅞″	Jack Rafter
72	1	7′ 0″	9′10¾″	Jack Rafter
73	1	9′ 0″	12′ 8¾″	Jack Rafter
74	1	11′ 0″	15′ 6⅝″	Jack Rafter
75	1	12′ 0″	16′11⅝″	Cripple Rafter
76	1	12′ 0″	16′11⅝″	Cripple Rafter
A	1	21′ 2½″	25′11¾″	Hip Rafter
B	1	21′ 2½″	25′11¾″	Part Hip and Part Valley
C	1	14′ 1¾″	17′ 3¾″	Valley Rafter
D	1	14′ 1¾″	17′ 3¾″	Valley Rafter
E	1	18′ 4⅝″	22′ 6¼″	Valley Rafter
F	1	18′ 4⅝″	22′ 6¼″	Part Hip and Part Valley
G	1	12′ 8¾″	15′ 7″	Valley Rafter
H	1	15′ 6⅝″	19′ 0⅝″	Valley Rafter
I	1	9′10¾″	12′ 1½″	Valley Rafter
J	1	18′ 4⅝″	22′ 6¼″	Valley Rafter
K	1	2′ 10″	3′ 5⅝″	Hip Rafter
L	1	8′ 0″	8′ 0″	Ridge
M	1	10′ 0″	10′ 0″	Ridge
N	1	18′ 0″	18′ 0″	Ridge
O	1	11′ 0″	11′ 0″	Ridge
P	1	8′ 0″	8′ 0″	Ridge Dormer
Q	1	19′ 0″	19′ 0″	Ridge

Figures used on the steel square: Common, jack and cripple rafters, 12″ on tongue, 12″ on blade. Mark on tongue for plumb cuts and on blade for level cuts.

Top cut for jack and cripple rafters, 12″ on tongue, 17″ on blade. Mark on blade for top cut.

Hip and valley rafters, 12″ on tongue, 17″ on blade.

Mark on tongue for plumb cuts and on blade for level cuts.

Top cut for hip and valley rafters, $8\frac{1}{2}''$ on tongue, $10\frac{3}{8}''$ on blade. Mark on blade for top cut.

PROBLEM NO. 7

Specifications.—Plate, main roof, $\frac{7}{8}'' \times 2''$.
Plate *A* around to *B*, $\frac{7}{8}'' \times 5''$.
Hip and valley rafters, $\frac{3}{4}'' \times 1\frac{1}{4}''$.
Common and jack rafters, $\frac{3}{8}'' \times \frac{7}{8}''$.
Ridge, $\frac{3}{8}'' \times 1\frac{1}{8}''$.
Projection, $2\frac{1}{2}''$.
Facia, $\frac{1}{2}''$.
Plancher level to plate level, $1\frac{3}{4}''$.
Pitch, $9''$ rise in one foot ($\frac{3}{8}$ pitch).
Dimensions (see plan, Figure 43).
Rafters spaced $2''$ on centers.

In framing the main rafters run hip *A* from ridge *N*, forming a butt joint against valley *C*, to the plate, giving support for valley *B* and ridge *L*. Run valley *K* from valley *H* to the wall line, giving support for valley *J*, hip *I* and ridge *Q*.

Hips *A* and *G* and valleys *B*, *C*, *H* and *K* all cross the plate at an angle of forty-five degrees and are laid out in the usual way for hip and valley rafters of equal pitch roofs.

Valleys *D* and *J* and hips *E*, *F* and *I* are laid out differently because they do not cross the plate at an angle of forty-five degrees and the same figures on the square will not apply. In each case it is necessary to

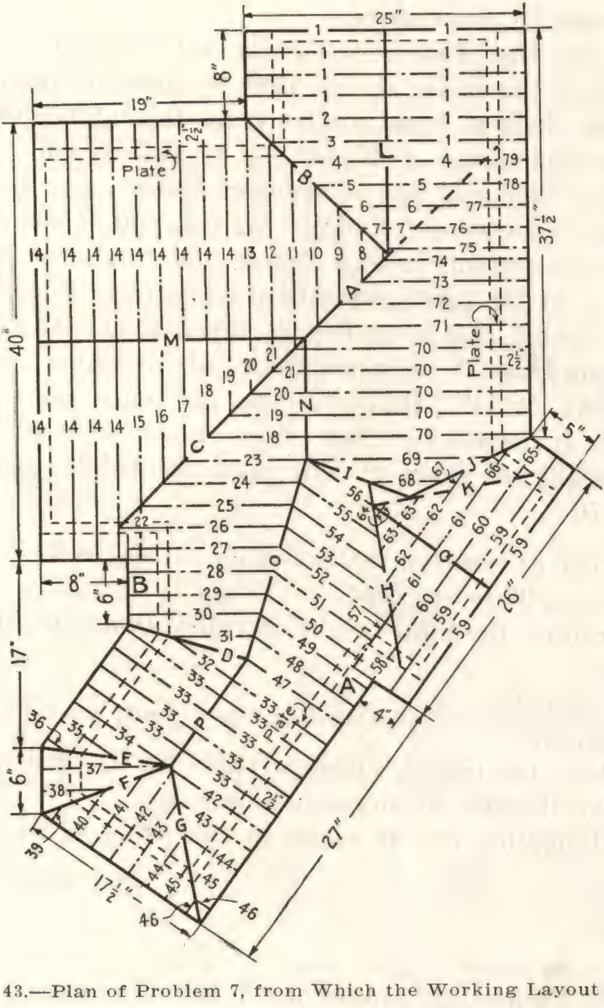


Figure 43.—Plan of Problem 7, from Which the Working Layout Is Made

determine the rise in inches per foot run before the length can be determined.

To Lay Out Valley D.—First determine the exact location of the valley on the plan by drawing light construction lines at right angles from the intersection of the two facia lines *A*, Figure 44, as at *J* and *K*. With *A* as a center and any convenient radius, arc the construction lines as at *L* and *M*. With *L* and *M* as centers and a convenient radius, bisect the angle as at *N*. From *A*, at the intersection of the two facia lines, draw in the center line of valley *D* through arc *N* until it intersects ridge *P*. Measure the run on the plan, *A* to *R*, Figure 44, or 11″. Before setting the fence and square, the rise in inches per foot of run must be determined. The height of ridge *P* will give the total height of valley *D*.

The run of common rafter No. 33 is 10½ feet.

The rise, 9″ in one foot.

Therefore, the total height of valley *D* will be 9x10½, or 94½″.

$$\frac{\textit{Rise in inches}}{\textit{Run in feet}} = \textit{rise in inches per foot, or } 8\ 7/12''.$$

That is, the rise in inches divided by the run in feet will give the rise in inches per foot run.

Working this out as given in the problem we have:

$$94\tfrac{1}{2} \div 11 = \frac{189}{2} \times \frac{1}{11} = 8\frac{7}{12}'' = \textit{rise in inches per foot.}$$

Set the fence and square at 8 7/12″ rise on the tongue and 12″ run on the blade. Mark on the tongue for all

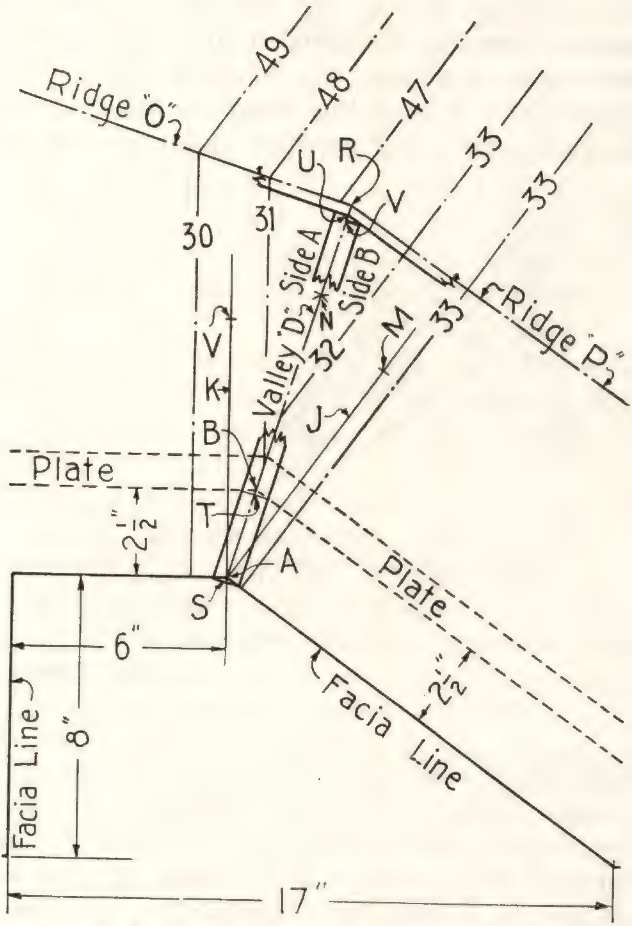


Figure 44.—Section Through Valley *D*, Figure 43

plumb cuts and on the blade for all level cuts. Press the fence firmly against the top edge of the stock to be used and produce the facia or first plumb line to the extreme right, *A*, Figure 45. Slide the fence to the left and measure on a level line from facia line *A* the run of the valley, 11″, and produce plumb line *R*, the ex-

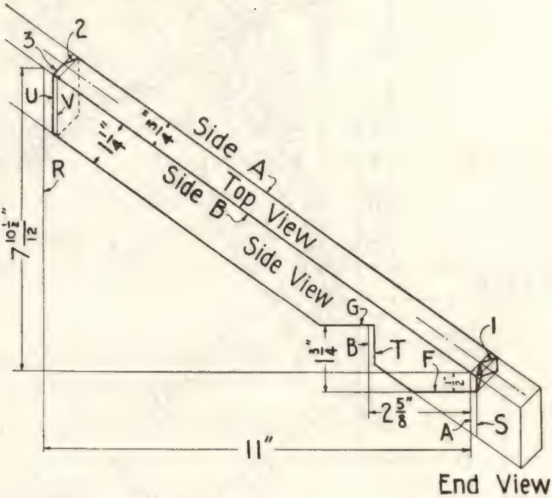


Figure 45.—Developed Length of Valley *D*

treme length of valley *D* to the center of ridge *P*. From this length deduct one-half the thickness of the ridge measured on the line of valley *D* or one-half the diagonal thickness of ridge *O* as at *R-U*, Figure 44, and produce plumb line *U*, Figure 45. Square this line across the top edge of the rafter and locate the center.

To lay out the top cut so that the valley will fit

into the intersection of ridges *P* and *O*, lay in a section of the valley full size as shown in Figure 44. At the point where the outside edge of the rafter intersects ridge *P* square a line across at right angles to the center line until it intersects the center line as at *V*, Figure 44. Measure forward on a level line from plumb line *U*, Figure 45, the distance *U-V*, Figure 44, and produce plumb line *V*, Figure 45. Connect plumb line *V* with the center line on the top edge as at *2*, top view, Figure 45. Side *B* is a square cut on plumb line *U* as at *3*.

To complete the lower end of the rafter measure in on a level line from facia line *A* the diagonal distance of the projection *A-B*, Figure 44, 2⅝″, and produce wall line *B*.

To eliminate notching into the crotch formed by the intersection of the two walls move wall line *B* out the distance *B-T*, Figure 44, and produce plumb line *T*, Figure 45. Measure down on facia line *A*, ½″, the width of the facia, and produce plancher level *F*. Measure up from plancher level *F*, 1¾″, locating plate level *G*.

To make the return on the facia line square facia line *A* across the top edge of the rafter and locate the center point. Measure forward on a level line from facia line *A*, on either side of the rafter, the distance *A-S*, Figure 44, and produce plumb line *S*, Figure 45. Connect plumb line *S* with the center point on the facia line as shown at *1*, top view, Figure 45. Cut on plumb line *S* and top cut *1* for the facia, on lines *T* and *G*

for the birdsmouth, on plumb line *V*, top cut *2*, plumb line *U* and top cut *3* for the fit against the ridge.

To Lay Out Hip E.—It will be necessary to determine how hips *E*, *F* and *G* and ridge *P* are to be

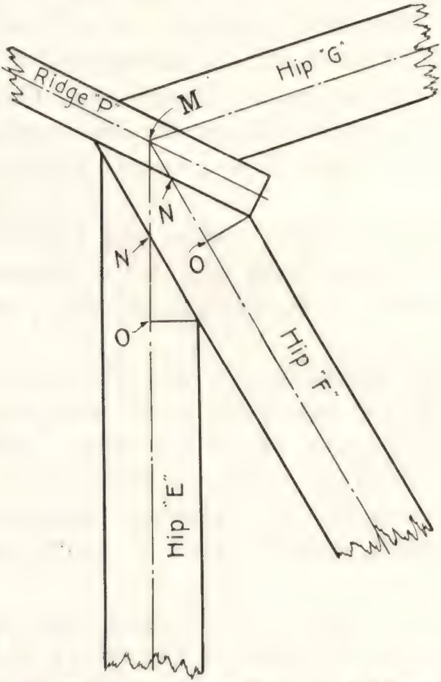


Figure 46.—Section Through Hips *E*, *F*, and *G* and Ridge *P*, Figure 43, Showing a Method of Framing the Rafters Together

framed into each other. One method is shown in Figure 46. Next, to determine the rise in inches per foot of run measure the run on the plan, *A-X*, Figure 48, or 11 11/12″. The height of ridge *P* will give the total height of hip *E*.

Run of common rafter No. 33 is $10\frac{1}{2}''$.
Rise, 9″ in one foot.

Therefore, the total height of ridge *P* will be $9 \times 10\frac{1}{2}$, or $94\frac{1}{2}''$.

$$\frac{\textit{Rise in inches}}{\textit{Run in feet}} = \textit{Rise in inches per foot, or } 7\ 11/12''.$$

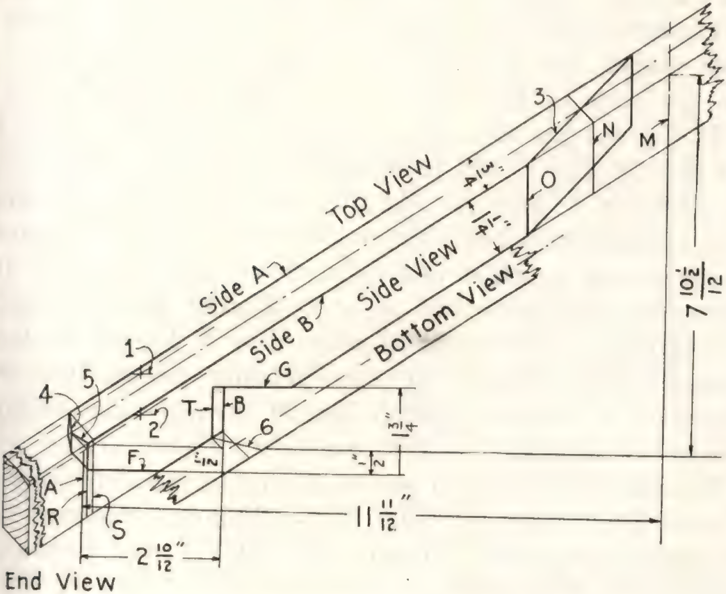


Figure 47.—Developed Length of Hip *E*

Working this out as given in the problem, we have: $94\frac{1}{2} \div 11\ 11/12 = 189/2 \div 143/12 = 189/2 \times 13/143 = 7\ 11/12$ = *rise in inches.*

Set the fence and square at 7 11/12″ rise on the tongue and 12″ run on the blade. Mark on the tongue

for all plumb cuts and on the blade for all level cuts. Press the fence firmly against the top edge of the stock to be used and produce the facia or first plumb line to the extreme left, *A*, Figure 47. Slide the fence to the right and measure on a level line from facia line *A* the run of hip *E*, 11 11/12″, and produce plumb line *M*, the extreme length to the center line of ridge *P*. From this length deduct the distance *M-N*, Figure 46, and produce plumb line *N*, Figure 47. Square this line across the top edge of the rafter and locate the center point.

To lay out the top cut so that the hip will fit against the side of hip *F*, lay in a section of the hip, full size, as shown in Figure 46. At the point where the outside edge of hip *E* intersects the outside edge of hip *F* square a line across at right angles to the center line until it intersects the center line as at *O*, Figure 46. Measure forward on a level line from plumb line *N*, Figure 47, the distance *N-O*, Figure 46, and produce plumb line *O*, Figure 47. Connect plumb line *O* through the center line on the top edge as at *3*, top view, Figure 47.

To complete the lower end of the rafter measure in on a level line from facia line *A* the diagonal distance of the projection, *A-B*, Figure 48, 2 10/12″ and produce wall line *B*, Figure 47.

To make a fit against the side of the plate at the proper angle, lay in a section of the hip as shown in Figure 48. At the point where the outside edge of the hip intersects the wall line, square a line across at right angles to the center line until it intersects the center line as at *T*, Figure 48. Measure forward on the side of the hip from wall line *B* the distance *T-B*,

Figure 48, and produce plumb line *T*, Figure 47. Square plumb line *B* across the bottom edge of the rafter and connect plumb line *T* through this center point as shown at *6*, bottom view. Measure down on facia line *A* ½″, the width of the facia, and produce plancher level *F*.

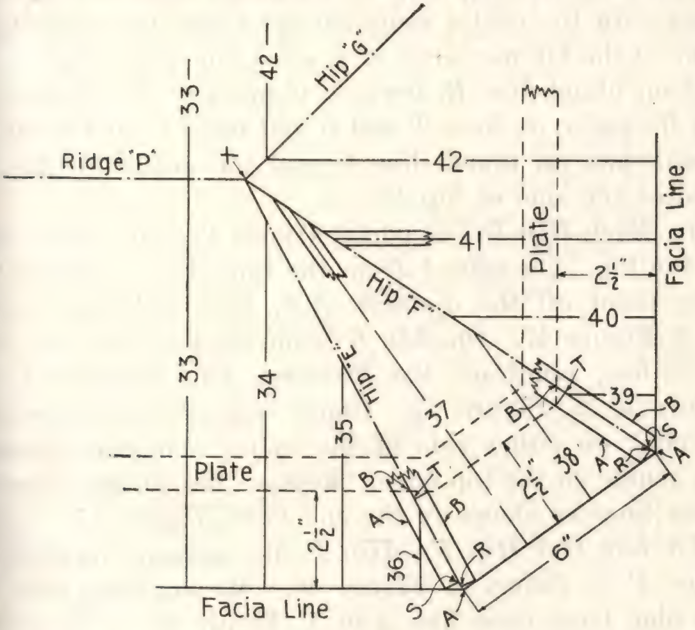


Figure 48.—Section Through *E*, *F*, and *G*, Figure 43, Showing Intersection of Plate and Facia Lines

Measure up from plancher level *F* 1¾″, locating plate level *G*.

To make the turn on the facia line lay in a section of the hip full size as shown in Figure 48. Where the outside edges of the hip intersect either facia line draw lines across at right angles to the center line until

they intersect the center line as at *R* and *S*. On side *A* of the rafter measure back the distance *A-S*, Figure 48, and produce plumb line *S*, Figure 47. On side *B* measure back the distance *A-R*, Figure 48, and produce plumb line *R*, Figure 47. Connect these two plumb lines with the center point on the facia line on the top edge of the hip as shown at *4* and *5*, top view, Figure 47. Cut on plumb line *R*, bevel *5*, plumb line *S* and bevel *4* for the facia, on lines *T* and *G* and bevel *6* for the birds-mouth and on plumb line *O* and top cut *3* for the fit against the side of hip *F*.

To Back Hip E.—Produce a level line on either side of the hip. On side *A* from the top edge, on this level line, point off the distance *A-S*, Figure 48, as shown at *1*, Figure 47. On side *B* from the top edge, on this level line, point off the distance *A-R*, Figure 48, as shown at *2*, Figure 47. Gauge a line through points *1* and *2* on either side of the rafter and also through the center on the top edge. Remove the corner between these lines as shown in the end view, Figure 47.

To Lay Out Hip F.—Hip *F* fits against the side of ridge *P* as shown in Figure 46. Measure the run on the plan from facia line *A* to *X*, Figure 48, or 12 8/12″. Next determine the rise in inches per foot of run. The total height of the rafter is the same as hip *E* or 94½″.

$$\frac{\textit{Rise in inches}}{\textit{Run in feet}} = \textit{Rise in inches per foot, or } 7\ 5/12''.$$

Working this out as given in the problem, we have:

$94\ 1/2 \div 12\ 8/12 = 189/2 \div 152/12 = 189/2 \times 12/152 = 7\ 5/12''$ = *rise in inches per foot.*

Set the fence and square at 7 5/12″ rise on the tongue nd 12″ run on the blade. Mark on the tongue for all lumb cuts and on the blade for all level cuts. Press he fence firmly against the top edge of the stock to be sed and produce the facia or first plumb line to the xtreme left, *A*, Figure 49. Slide the fence to the right

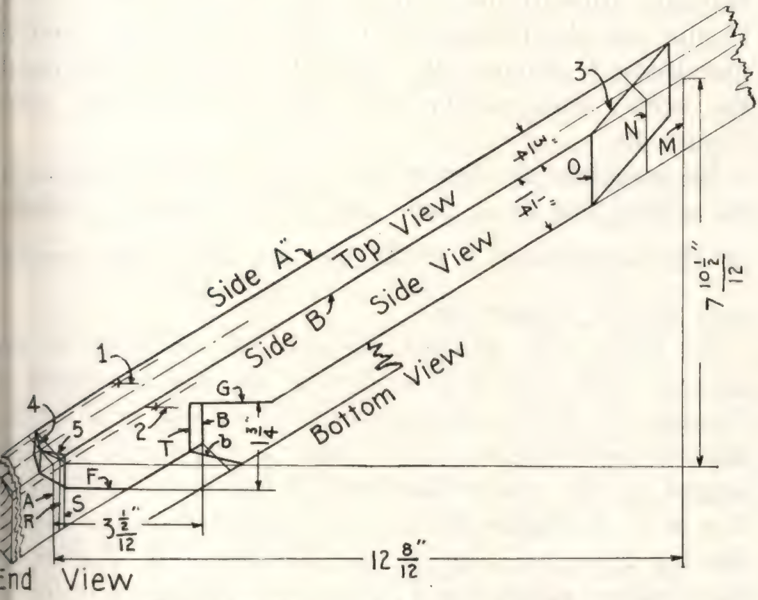


Figure 49.—Developed Length of Hip *F*

nd measure on a level line from facia line *A* the run of ip *F*, 12 8/12″, and produce plumb line *M*, the extreme ength to the center line of ridge *P*. From this length educt the distance *M-N*, Figure 46, and produce plumb ine *N*, Figure 49. Square this line across the top edge f the rafter and locate the center point.

To lay out the top cut so that the hip will fit against the side of ridge *P*, lay in a section of the hip, full size as shown in Figure 46. At the point where the outside edge of the hip intersects the outside edge of ridge *P* square a line across at right angles to the center line until it intersects the center line as at *O*, Figure 46. Measure forward on a level line from plumb line *N*, Figure 49, the distance *N-O*, Figure 46, and produce plumb line *O*, Figure 49. Connect plumb line *O* through the center line on the top edge as at *3*, top view, Figure 49.

To complete the lower end of the rafter measure in on a level line from facia line *A* the diagonal distance of the projection, *A-B*, Figure 48, $3\frac{1/2}{12}''$ and produce wall line *B*, Figure 49.

To make a fit against the side of the plate at the proper angle, lay in a section of the hip as shown in Figure 48. At the point where the outside edge of the hip intersects the wall line square a line across at right angles to the center line until it intersects the center line as at *T*, Figure 48. Measure forward on the side of the hip from wall line *B*, the distance *T-B*, Figure 48 and produce plumb line *T*, Figure 49. Square wall line *B* across the bottom edge of the rafter, locate the center point, and connect plumb line *T* through this center point as shown at *6*, bottom view, Figure 49. Measure down on facia line *A* from the top edge of the rafter ½″, the width of the facia and locate plancher level *F*. Measure up from plancher level *F*, 1¾″, locating plate level *G*.

To make the return on the facia line lay in a section of the hip, full size, as shown in Figure 48. Where the outside edges of the hip intersect the facia line, draw lines across at right angles to the center line until they intersect the center line as at *R* and *S*. On side *A* of the rafter measure back the distance *A-R,* Figure 48, and produce plumb line *R,* Figure 49. On side *B* measure back the distance *A-S,* Figure 48, and produce plumb line *S,* Figure 49. Connect these two plumb lines with the center point on the facia line on the top edge as shown at *4* and *5,* top view, Figure 49. Cut on plumb line *R,* bevel *4,* plumb line *S* and bevel *5* for the facia; on lines *T* and *G* and bevel *6* for the birdsmouth and on plumb line *O* and top cut *3* for the fit against ridge *P.*

To Back Hip F.—Produce a level line on either side of the rafter. On side *A,* from the top edge, on this level line, point off the distance *A-R,* Figure 48, as shown at *1,* Figure 49. On side *B,* from the top edge, on this level line, point off the distance *A-S,* Figure 48, as shown at *2,* Figure 49. Gauge a line through the points *1* and *2* on either side of the rafter and also through the center on the top edge. Remove the corner between these lines as shown in the end view, Figure 49.

To Lay Out Hip I.—Measure the run on the plan from the intersection of hip *K* and valley *J* and the intersection of ridges *N* and *O* as shown in the section *M* to *R,* Figure 50, or 10′1″.

Next determine the rise in inches per foot of run. The extreme height of the hip is determined by the run of common rafter No. 70.

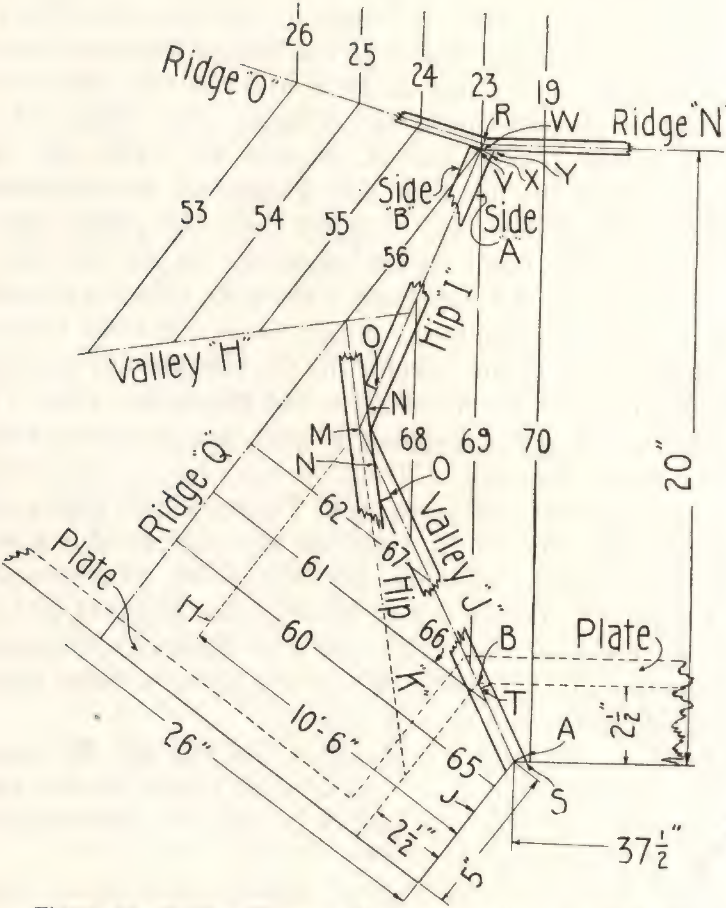


Figure 50.—Section Through Hip *I* and Valley *J*, Figure 43

Run of common rafter No. 70— 20′0″
Rise 9″ in one foot—
Therefore, the total height of hip *I* will be 9x20, or 180″.

The height of the lower end of the hip is determined by the extreme height of valley *J*. Project a line on the plan parallel with ridge *Q* from the intersection of hip *K*, valley *J* and hip *I* as shown in Figure 50. Measure the run from this line to the facia line as *H* to *J*, or 10′6″. Multiplying this run by 9″ rise in one foot will give the height of the lower end of hip *I*, or 94½″.

Extreme height of hip I—	180″
Lower height of hip I—	94½″
Height hip I rises in its run=	85½″

$\dfrac{\textit{Rise in inches}}{\textit{Run in feet}}$ = *rise in inches per foot, or* $8\frac{5\frac{1}{2}}{12}$″.

Working this out as given in the problem we have: $85\,1/2 \div 10\,1/12 = 171/2 \div 121/12 = 171/2 \times 12/121 =$
$8\frac{5\frac{1}{2}}{12}$″ *rise in inches per foot.*

Set the fence and square at $8\frac{5\frac{1}{2}}{12}$″ on the tongue and 12″ on the blade. Mark on the tongue for all plumb cuts and on the blade for all level cuts. Press the fence firmly against the top edge of the stock to be used and produce the first plumb line *M*, Figure 51, to the extreme right. Slide the fence to the left and measure on a level line from plumb line *M* the run of hip *I*, or 10 1/12″, and produce plumb line *R*, the extreme length to the intersection of ridges *N* and *O*. From this length

deduct the distance *R-W*, Figure 50, and produce plumb line *W*, Figure 51. Square this line across the top edge and locate the center point.

To lay out the top cut so that the hip will fit against the sides of ridges *N* and *O* lay in a section of the hip,

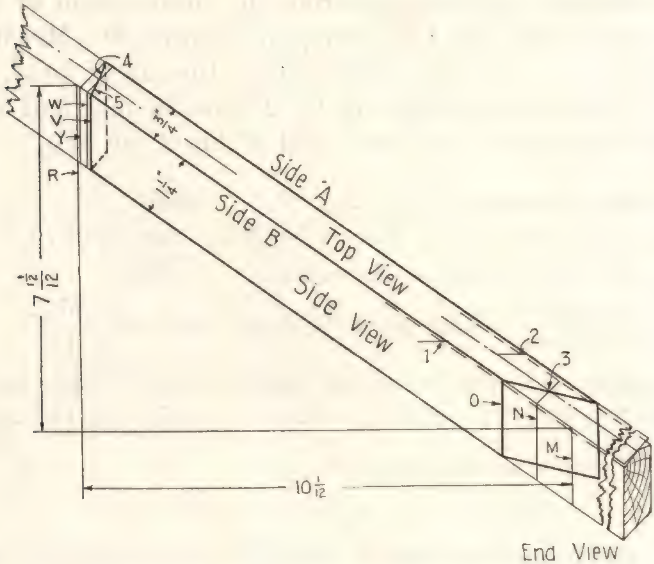


Figure 51.—Developed Length of Hip *I*

full size, as shown in Figure 50. At the point where the outside edge of hip *I* intersects ridge *O*, square a line across at right angles until it intersects the center line as at *V*. Likewise square a line across at right angles to the center line from the point *W* until it intersects the outside edge of the rafter as at *X*. On side *B*

measure forward on a level line from plumb line *W*, Figure 51, the distance *W-V*, Figure 50, and produce plumb line *V*, Figure 51. On side *A* measure back on a level line from plumb line *W* the distance *X-Y*, Figure 50, and produce plumb line *Y*, Figure 51. Connect plumb line *Y* with the center point on the top edge as at *4*. Connect plumb line *V* with the center point on the top edge as at *5*, top view, Figure 51.

To complete the lower end of the rafter, first determine the top cut by drawing in a section of the hip, full size, as shown in Figure 50. Where the outside edge of the hip intersects hip *K*, square a line across at right angles to the center line until it intersects the center line as at *O*. Measure back on a level line from plumb line *M*, Figure 51, the distance *M-N*, Figure 50, and produce plumb line *N*, Figure 51. Square this line across the top edge of the rafter and locate the center point. Measure in from plumb line *N* the distance *N-O*, Figure 50, and produce plumb line *O*, Figure 51. Connect plumb line *O* through the center point on the top edge as shown at *3*, Figure 51. Cut on plumb line *O* and bevel *3* for the fit against the side of hip *K*, on plumb line *V* and top cut *5* for the fit against the side of ridge *O* and on plumb line *Y* and top cut *4* for the fit against the side of ridges *O* and *N*.

To Back Hip I.—Produce a level line on either side of the rafter. On side *A*, from the top edge, on this level line, point off the distance *X-Y*, Figure 50, as shown at *2*, Figure 51. On side *B*, from the top edge, on this level line, point off the distance *V-W*, Figure

50, as shown at *1*, Figure 51. Gauge a line through the points *1* and *2* on either side of the hip and also through the center on the top edge. Remove the corner between these lines as shown in the end view, Figure 51.

To Lay Out Valley J.—Measure the run on the plan from the facia line to the intersection of hips *I* and *K*, *A-M*, Figure 50, or 11′10″. Next determine the rise in inches per foot. The total height of valley *J* was determined in laying out the preceding hip *I* which was found to be 94½″.

$$\frac{\textit{Rise in inches}}{\textit{Run in feet}} = \textit{rise in inches per foot, or } 8''.$$

Working this out as given in the problem, we have: 94 1/2 ÷ 11 10/12 = 189/2 ÷ 142/12 = 189/2 x 12/142 = 8″ *rise in inches per foot.*

Set the fence and square at 8″ rise on the tongue and 12″ run on the blade. Mark on the tongue for all plumb cuts and on the blade for all level cuts. Press the fence firmly against the top edge of the stock to be used and produce the first plumb line to the extreme right, or facia line *A*, Figure 52. Slide the fence to the left and measure on a level line from facia line *A*, the run of valley *J*, or 11 10/12″, and produce plumb line *M*, the extreme length to the center of hip *K*. From this length deduct the distance *M-N*, Figure 50, and produce plumb line *N*, Figure 52. Square this line across the top edge and locate the center point.

To lay out the top cut so that the valley will fit

against the side of hip K, lay in a section of the valley, full size, as shown in Figure 50. At the point where the outside edge of the valley intersects the outside edge of hip K square a line across at right angles to the center line until it intersects the center line as at O,

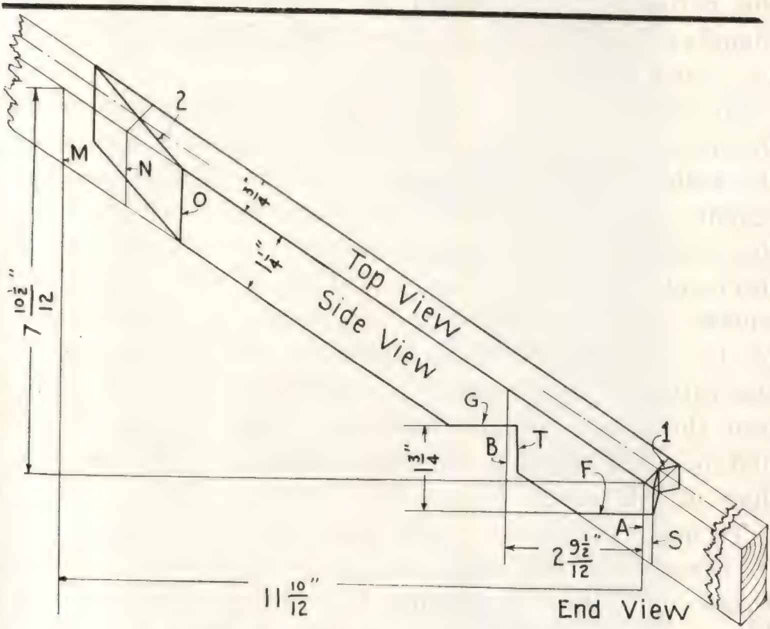


Figure 52.—Developed Length of Valley J

Figure 50. Measure forward on a level line from plumb line N, Figure 52, the distance N-O, Figure 50, and produce plumb line O, Figure 52. Connect plumb line O through this center point on the top edge as shown at 2, top view, Figure 52.

To complete the lower end of the valley measure in on a level line from facia line *A* the diagonal distance of the projection *A-B*, or $2\frac{9\frac{1}{2}}{12}''$, and produce wall line *B*. Measure down on facia line *A* from the top edge of the rafter ½″, the width of the facia, and produce plancher level *F*. Measure up from plancher level *F* 1¾″, and locate plate level *G*.

To make the return on the facia line and to determine the distance to advance the wall line lay in a section of the valley, full size, as shown in Figure 50. Where the outside edge of the valley intersects the plate square a line across at right angles to the center line until it intersects the center line as at *T*, Figure 50. Also square a line across from facia line *A* at right angles to the center line until it intersects the outside edge of the valley. To advance the wall line to avoid notching into the crotch of the building measure forward the distance *B-T*, Figure 50, from plumb line *B*, and produce plumb line *T*, Figure 52.

To make the return on the facia line, square facia line *A* across the top edge and locate the center point. From plumb line *A* measure forward the distance *A-S*, Figure 50, and produce plumb line *S*, Figure 52. Connect plumb line *S* on either side of the valley with the facia line on the center point on the top edge as shown at *1*, Figure 52. Cut on plumb line *S* and top cut *1* for the facia, on lines *T* and *G* for the birdsmouth and on plumb line *O* and top cut *2* for the fit against hip *K*.

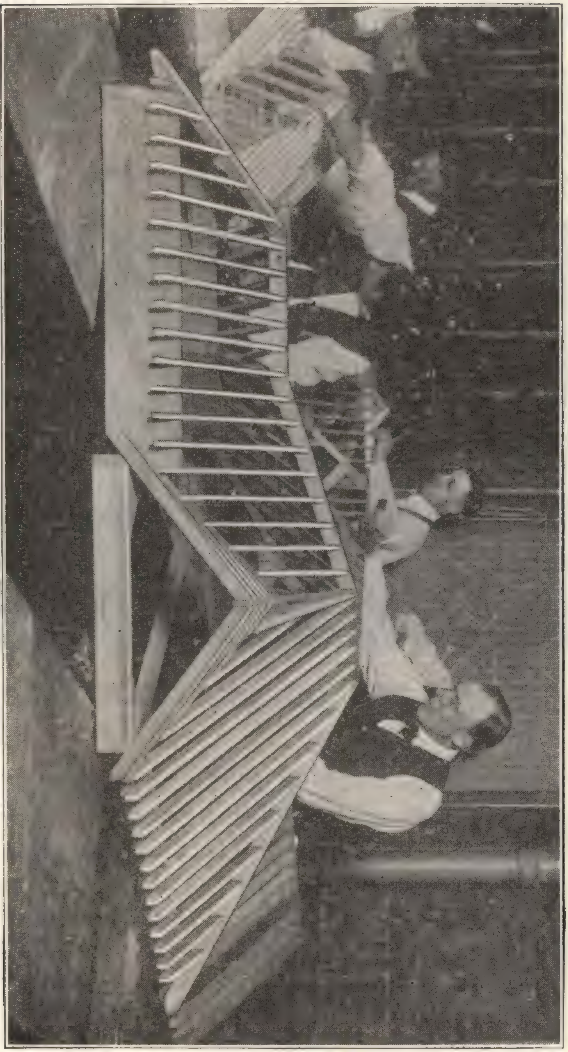


Figure 53.—Front and Right Side Elevation, Problem 7, Showing the Method of Framing the Rafters

To Assemble the Roof.—Assemble the rafters as shown in the elevations, Figures 53 and 54. Set up hips A and C first. Then ridge M, supported by a pair of No. 14 common rafters. Then valley B and ridge L, supported by a pair of No. 1 common rafters. Then hips E, F and G and ridge P, supported by a pair of No.

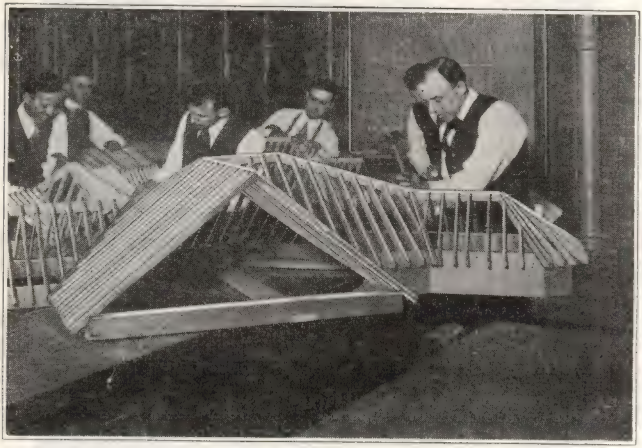


Figure 54.—Rear and Left Side Elevation, Problem 7, Showing the Method of Framing the Rafters

33 common rafters, noticing that hips E and F do not intersect the corner of the building because they do not cross the plate at an angle of forty-five degrees. They must intersect on the facia line. Then set up valley D, ridges N and O and lastly valleys H, J and K, hip I and ridge Q, supported by a pair of No. 59 common rafters.

RUNS AND LENGTHS OF RAFTERS USED IN FRAMING PROBLEM NO. 7—⅜ PITCH

Number of Rafters	Quantity of Rafters	Runs	Lengths	Kind of Ratfers
1	10	12′ 6″	15′ 7½″	Common Rafters
2	1	12′ 6″	15′ 7½″	Jack Rafter
3	1	10′ 6″	13′ 1½″	Jack Rafter
4	1 pair	8′ 6″	10′ 7½″	Jack Rafters
5	1 pair	6′ 6″	8′ 1½″	Jack Rafters
6	1 pair	4′ 6″	5′ 7½″	Jack Rafters
7	1 pair	2′ 6″	3′ 1½″	Jack Rafters
8	1	5′ 0″	6′ 3″	Cripple Rafter
9	1	9′ 0″	11′ 3″	Cripple Rafter
10	1	13′ 0″	16′ 3″	Cripple Rafter
11	1	16′ 0″	20′ 0″	Jack Rafter
12	1	18′ 0″	22′ 6″	Jack Rafter
13	1	20′ 0″	25′ 0″	Jack Rafter
14	13	20′ 0″	25′ 0″	Common Rafters
15	1	15′ 0″	18′ 9″	Jack Rafter
16	1	13′ 0″	16′ 3″	Jack Rafter
17	1	11′ 0″	13′ 9″	Jack Rafter
18	1 pair	9′ 0″	11′ 3″	Jack Rafter
19	1 pair	7′ 0″	8′ 9″	Jack Rafters
20	1 pair	5′ 0″	6′ 3″	Jack Rafters
21	1 pair	3′ 0″	3′ 9″	Jack Rafters
22	1	1′ 0″	1′ 3″	Jack Rafters
23	1	11′ 0″	13′ 9″	Cripple Rafter
24	1	12′ 4½″	15′ 5⅝″	Cripple Rafter
25	1	13′ 9″	17′ 2¼″	Cripple Rafter
26	1	15′ 1½″	18′10⅞″	Cripple Rafter
27	1	13′ 9″	17′ 2¼″	Jack Rafter
28	1	13′ 1½″	16′ 4⅞″	Jack Rafter
29	1	12′ 6″	15′ 7½″	Jack Rafter
30	1	11′10½″	14′10⅛″	Jack Rafter
31	1	8′ 1½″	10′ 1⅞″	Cripple Rafter
32	1	5′ 8″	7′ 1″	Jack Rafter
33	9	10′ 6″	13′ 1½″	Jack Rafters
34	1	9′ 5″	11′ 9¼″	Jack Rafter
35	1	5′ 9½″	7′ 2⅞″	Jack Rafter
36	1	2′ 0½″	2′ 6⅝″	Jack Rafter
37	1	10′ 7″	13′ 2¾″	Jack Rafter
38	1	5′ 4″	6′ 8″	Jack Rafter
39	1	2′ 3½″	2′10⅜″	Jack Rafter
40	1	5′ 3″	6′ 6¾″	Jack Rafter
41	1	8′ 3″	10′ 3¾″	Jack Rafter
42	1 pair	10′ 0″	12′ 6″	Jack Rafters
43	1 pair	8′ 0″	10′ 0″	Jack Rafters
44	1 pair	6′ 0″	7′ 6″	Jack Rafters

RUNS AND LENGTHS OF RAFTERS USED IN FRAMING PROBLEM NO. 7—3/8 PITCH—Continued

Number of Rafters	Quantity of Rafters	Runs	Lengths	Kind of Rafters
45	1 pair	4′ 0″	5′ 0″	Jack Rafters
46	1 pair	2′ 0″	2′ 6″	Jack Rafters
47	1	10′ 7½″	13′ 3⅜″	Jack Rafter
48	1	11′ 4″	14′ 2″	Jack Rafter
49	1	12′ 0½″	15′ 0⅝″	Jack Rafter
50	1	12′ 9″	15′11¼″	Jack Rafter
51	1	13′ 8″	17′ 1″	Jack Rafter
52	1	12′ 4½″	15′ 5⅝″	Jack Rafter
53	1	11′ 1″	13′10¼″	Jack Rafter
54	1	9′ 9½″	12′ 2⅞″	Jack Rafter
55	1	8′ 6″	10′ 7½″	Jack Rafter
56	1	7′ 2½″	9′ 0⅛″	Jack Rafter
57	1	6′ 0″	7′ 6″	Jack Rafter
58	1	4′ 0″	5′ 0″	Jack Rafter
59	4	13′ 0″	16′ 3″	Common Rafters
60	1 pair	9′ 0″	11′ 3″	Jack Rafters
61	1 pair	7′ 0″	8′ 9″	Jack Rafters
62	1 pair	5′ 0″	6′ 3″	Jack Rafters
63	1 pair	3′ 0″	3′ 9″	Jack Rafters
64	1 pair	1′ 0″	1′ 3″	Jack Rafters
65	1	4′ 0″	5′ 0″	Jack Rafter
66	1	4′ 1½″	5′ 1⅞″	Cripple Rafter
67	1	2′ 4″	2′11″	Cripple Rafter
68	1	7′ 9″	9′ 8¼″	Cripple Rafter
69	1	17′ 0″	21′ 3″	Jack Rafter
70	5	20′ 0″	25′ 0″	Jack Rafters
71	1	19′ 0″	23′ 9″	Jack Rafter
72	1	17′ 0″	21′ 3″	Jack Rafter
73	1	15′ 0″	18′ 9″	Jack Rafter
74	1	13′ 0″	16′ 3″	Jack Rafter
75	1	12′ 0″	15′ 0″	Jack Rafter
76	1	10′ 0″	12′ 6″	Jack Rafter
77	1	8′ 0″	10′ 0″	Jack Rafter
78	1	6′ 0″	7′ 6″	Jack Rafter
79	1	4′ 0″	5′ 0″	Jack Rafter
A	1	24′ 9″	28′ 0⅛″	Part Hip and Part Valley
B	1	17′ 8⅛″	28′ 0⅛″	Valley Rafter
C	1	24′ 0½″	27′ 2½″	Valley Rafter
D	1	11′ 0″	13′ 3″	Valley Rafter
E	1	11′11″	14′ 3½″	Hip Rafter
F	1	12′ 8″	14′11″	Hip Rafter
G	1	14′10⅛″	16′ 9¾″	Hip Rafter
H	1	16′11⅝″	19′ 2½″	Valley Rafter

RUNS AND LENGTHS OF RAFTERS USED IN FRAMING PROBLEM NO. 7—3/8 PITCH—Continued

Number of Rafters	Quantity of Rafters	Runs	Lengths	Kind of Rafters
I	1	10′ 1″	12′ 3½″	Hip Rafter
J	1	11′10″	14′ 3″	Valley Rafter
K	1	14′10⅛″	16′ 9¾″	Part Hip and Part Valley
L	1	20′ 6″	20′ 6″	Ridge
M	1	24′ 0″	24′ 0″	Ridge
N	1	11′ 0″	11′ 0″	Ridge
O	1	19′ 0″	19′ 6″	Ridge
P	1	11′ 4″	11′ 4″	Ridge
Q	1	13′ 0″	13′ 0″	Ridge

Figures used on the steel square:

Common, jack and cripple rafters, 9″ on tongue, 12″ on blade. Mark on tongue for all plumb cuts and on blade for all level cuts.

Top cut for jack and cripple rafters, intersecting a hip or valley rafter that crosses the plate at an angle of 45 degrees, 12″ on tongue, 15″ on blade. Mark on blade for top cut.

Hip and valley rafters that cross the plate at an angle of 45 degrees, 9″ on tongue, 17″ on blade. Mark on tongue for all plumb cuts and on blade for all level cuts.

Top cut for hip and valley rafters that cross the plate at an angle of 45 degrees, 8½″ on tongue, 9⅝″ on blade. Mark on blade for top cut.

Valley *D*, $8\frac{7''}{12}$ on tongue, 12″ on blade.

Hip *E*, $7\frac{11''}{12}$ on tongue, 12″ on blade.

Hip *F*, $7\frac{5''}{12}$ on tongue, 12″ on blade.

Hip *I*, $8\frac{5\frac{1}{2}''}{12}$ on tongue 12″ on blade.

Valley *J*, 8″ on tongue, 12″ on blade.

Mark on tongue for all plumb cuts and on blade for all level cuts.

Top cut for valleys *D* and *J* and hips *E*, *F* and *I*; refer to the text for method of determining these top cuts.

CHAPTER V

HOW TO FRAME A ROOF OF UNEQUAL PITCH

An unequal pitch roof is a roof formed by the intersection of two roof surfaces having different pitches, one surface sloping more than the other. The hip and valley rafters form the dividing line, the roof surface on one side of the rafters being framed to one pitch and the roof surface on the opposite side of the rafters to a greater or lesser pitch.

The plates for the two roof surfaces are at different heights, those on the short common side or steeper pitch being higher than the plates on the long common side or lower pitch. The hip and valley rafters travel the diagonal distance of an oblong with reference to the plate in comparing them with the framing of a hip and valley rafter for a roof of equal pitch which travels the diagonal distance of a square and crosses the plate at an angle of forty-five degrees.

The center lines of the hip and valley rafters must intersect the facia line at the extreme corners or returns on the facia line and because they travel the diagonal distance of an oblong they are thrown to one side of the corner of the building or the return walls, crossing the plates to an angle at one side of the corner of the building. The common and jack rafters, as in any other roof, cross the plates at right angles.

This roof creates several interesting framing prob-

lems, which at first may appear difficult, although simple when once the basic principles are understood.

Specifications.—Plate, long common side, 7/8" x 2 1/2".
Plate, short common side, 7/8" x 3 1/8".
Hip and valley rafters, 3/4" x 1 1/4".
Common and jack rafters, 3/8" x 7/8".
Ridge, 3/8" x 1 1/8".
Projection, 2".
Facia, 5/8".
Plancher level to plate level, short common rafters, 2 5/8".
Plancher level to plate level, long common rafters, 2".
Pitch, long common rafters, 12" rise in one foot (1/2 pitch).
Dimensions (see plan, Figure 55).
Rafters spaced 2" on centers.

Layout.—A full size working layout of the plan, Figure 55, should be drawn on a board or sheet of detail paper. The layout will represent a scale of 1" to the foot. In applying the various measurements full size substitute the word feet for inches in listing the runs and lengths of the rafters. Number each rafter and ridge as shown on the plan. Put the corresponding numbers on the rafters as they are laid out so as to insure ready identification and proper location during the erection of the roof.

It will also be necessary to develop a profile of both the long and short common rafters on the layout as shown in Figure 56 so as to determine the proper

heights of the walls or plate levels. First, draw a profile of the long common rafters, the specifications calling for a half pitch roof, or rafters rising 12″ in one foot of run. In a half pitch roof, the run and the rise are the same, so if the run of the long common rafter is 11″ (see plan, Figure 55) the total rise of the

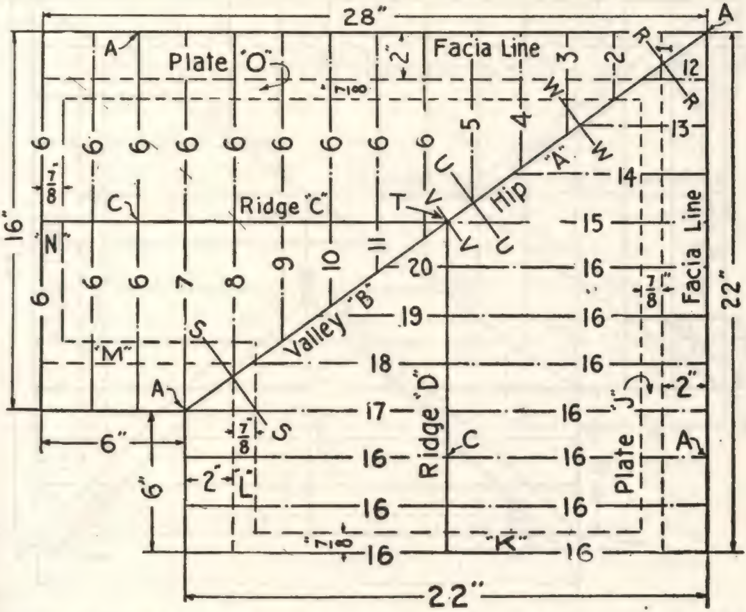


Figure 55.—Plan of Hip and Valley Roof of Unequal Pitch, from Which the Working Layout Is Made

rafter must also be 11″. With the total rise of the roof known, draw a profile of the short common rafter, the run of which is 8″, thus determining the pitch of the short common rafters.

In accordance with the specifications, which give the

desired width of the facia and projection, locate the plate levels on either rafter. It will be discovered that if the plates on walls *J*, *K* and *L* which support the long common rafters were on the same level or height as

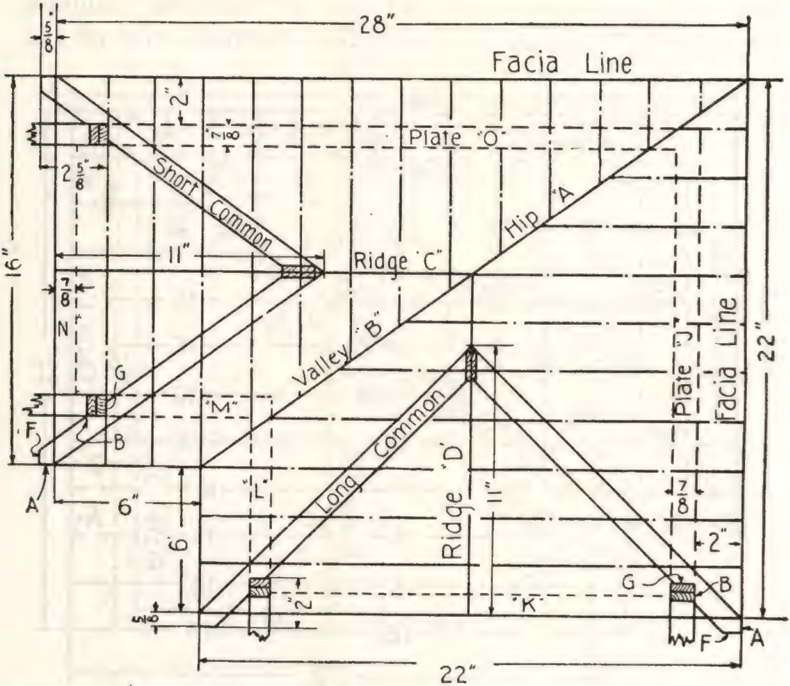


Figure 56.—Common Rafters Developed on the Plan. With the Pitch, Projection, Width of Facia and Plancher Levels Known, the Heights of the Plates Can Be Determined

the plates on walls *M*, *N* and *O* which support the short common rafters, the birdsmouth on the long common rafters would almost cut the rafters in two. To overcome this difficulty the plates on walls *J*, *K* and *L*

which support the long common rafters are dropped sufficiently to get a good seat cut on the plates and yet to not weaken the rafter at the birdsmouth. With the birdsmouths developed independently on both the long and short common rafters, measure the height of each plate level from the plancher level and subtract the two figures, which will give the difference in the heights of the two plate levels, 5/8″, the plancher level being level throughout the entire roof.

To Lay Out the Long Common Rafter.—The pitch of long common rafters No. 16 required by the specifications is 12″ rise in one foot. The run is taken from the layout, Figure 55, measuring from the facia line to center line of ridge *D, A-C,* or 11″. Set the fence and square at 12″ rise on the tongue and 12″ run on the blade. Mark on the tongue for all plumb cuts and on the blade for all level cuts. Press the fence firmly against the top edge of the stock to be used and produce the facia line or first plumb line to the extreme right, *A,* Figure 57. Slide the fence to the left and measure on a level line from facia line *A* the run of the rafter, 11″, and produce plumb line *C,* Figure 57, the extreme length of the rafter to the center line of ridge *D*. From this length deduct one-half the thickness of the ridge, 3/16″, and produce plumb line *D,* the cutting length of the rafter against the ridge.

To complete the lay-out of the lower end of the rafter measure in from facia line *A*, measuring on a level line, 2″, the width of the projection, locating wall line *B*. Measure down on facia line *A* from the top edge of the

rafter, ⅝″, the width of the facia, locating plancher level F. Measure up from plancher level *F*, measuring on a plumb line, 2″ (take this distance from the layout, Figure 56) locating plate level *G*. Cut on line *A* for the

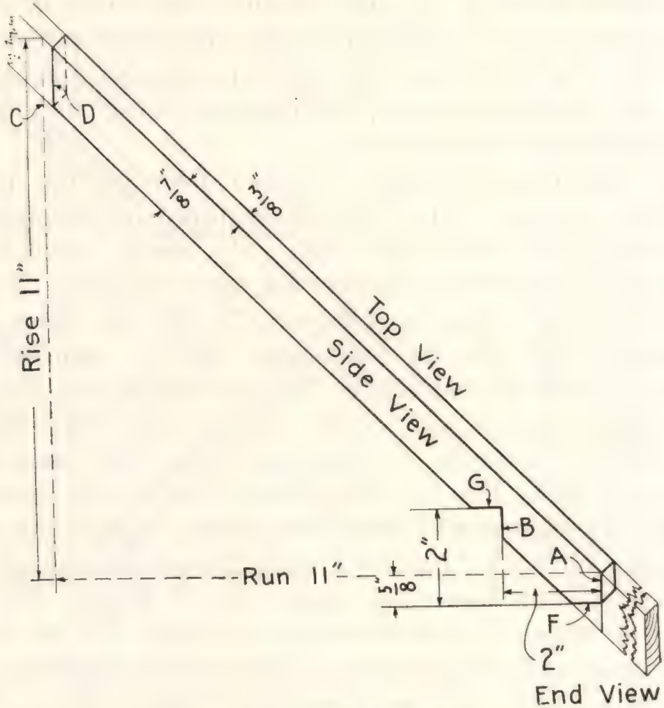


Figure 57.—Developed Length of Long Common Rafter No. 16

facia, on line *F* for the plancher level, on lines *G* and *B* for the birdsmouth and on line *D* for the cut against the ridge.

To Lay Out Jack Rafters on Long Common Side.—The lengths of jack rafters Nos. 12, 13, 14 and 15 are

determined in the same manner as for the preceding common rafter No. 16, since they are a part of the length of it. Take the runs from the layout, Figure 55, measuring from facia line *A* to the center of the hip.

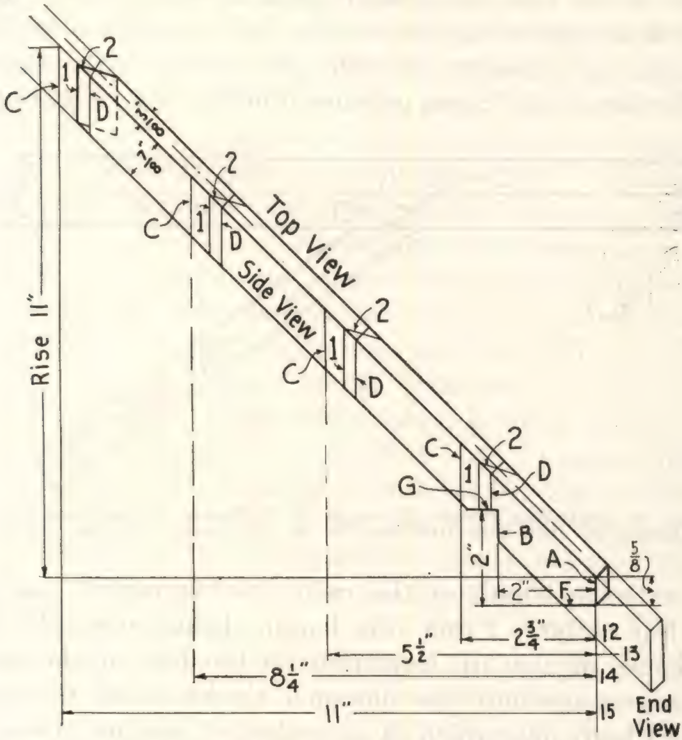


Figure 58.—Developed Length of Jack Rafters Nos. 12, 13, 14 and 15

The four rafters are shown developed on the side of a single rafter, Figure 58. In practice these would be laid out separately but are here laid out over one another to save space and to avoid repetition. Press the

fence firmly against the top edge of the stock to be used, using the same figures on the square as for the previous rafter, and produce the facia line or first plumb line to the extreme right, *A*, Figure 58. Slide the fence to the left and measure on a level line from facia line *A* the run of rafter No. 12, 2¾″; the run of rafter No. 13, 5½″; the run of rafter No. 14, 8¼″; the run of rafter No. 15, 11″; and produce plumb line *C*, Figure 58,

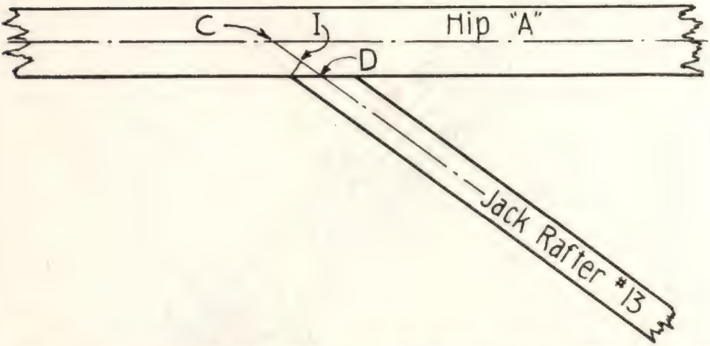


Figure 59.—Full Size Section Through *W-W* Figure 55, Showing Intersection of Jack and Hip Rafters on the Long Common Side

the extreme length of the rafter to the center line of the hip rafter. From this length deduct one-half the thickness of the hip measured on the line of the jack rafter, or one-half the diagonal thickness of the hip, *C-D*, Figure 59, which is an enlarged section through *W-W*, Figure 55, and produce plumb line *D*, Figure 58. Square this line across the top edge of the rafter and locate the center.

To simplify picking up the bevel for the top cut, draw in a section of the hip and jack rafter, full size, on

the layout, Figure 55, as shown in the section, Figure 59. Where the outside edges of the jack rafter intersect the outside edge of the hip rafter, square a line across at right angles to the center line until it intersects the center line as at *1*, Figure 59.

To lay out the top cut so that the jack rafters will fit against the side of the hip rafter at the proper angle, measure back on a level line from plumb line *D*, on the side of the rafter, Figure 58, the distance *D-1*, Figure 59, and produce plumb line *1*, Figure 58. Connect plumb line *1* through plumb line *D* on the center line as shown at *2*, top view, Figure 58. The lower end of the rafter is a duplicate of the long common rafter. Measure in from facia line *A*, measuring on a level line, 2″, the width of the projection, locating wall line *B*. Measure down on facia line *A*, from the top edge of the rafter, ⅝″, the width of the facia, locating plancher level *F*. Measure up from plancher level *F*, measuring on a plumb line, 2″, locating plate level *G*. Cut on line *A* for the facia, on line *F* for the plancher level, on lines *G* and *B* for the birdsmouth and on bevel *2* on the top edge and plumb line *1* for the cheek cut against the hip rafter.

The lengths of jack rafters Nos. 17, 18, 19 and 20 are determined in the same manner as for the preceding jack and common rafters, with the exception that the top and bottom cuts are different. Take the runs from the layout, Figure 55, measuring from the center of the ridge to the center of the valley rafter. The four rafters are shown developed on the side of a single rafter, Figure 60. In practice these would be laid out

separately but are here laid out over one another to save space and to avoid repetition. Press the fence firmly against the top edge of the stock to be used and

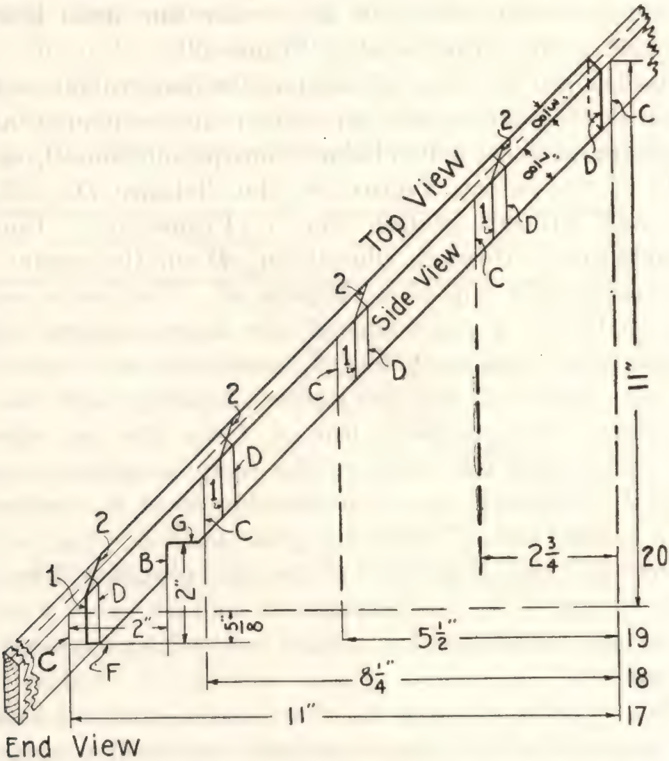


Figure 60.—Developed Length of Jack Rafters Nos. 17, 18, 19 and 20

produce the first plumb line to the extreme right, *C*, Figure 60. Slide the fence to the left and measure on a level line the run of rafter No. 17, 11″; the run of rafter No. 18, 8¼″; the run of rafter No. 19, 5½″ and

the run of rafter No. 20, 2¾″; and produce plumb line *C*, Figure 60, the extreme length of the jack rafters from the center line of valley *B* to the center line of ridge *D*. From the top end of the jack rafters deduct one-half the thickness of the ridge, 3/16″, and produce plumb line *D*, the cutting length of the rafter against the ridge.

The bottom ends of all four rafters are beveled to make a fit against the side of the valley, and jack rafter No. 17 also has a bearing on the plate so that the plancher level and birdsmouth must be laid out as for the common rafter. To lay out the birdsmouth for rafter No. 17, measure in from plumb line *A*, Figure 60, measuring on a level line, 2″, the width of the projection, locating wall line *B*. Measure down on plumb line *A*, from the top edge of the rafter, ⅝″, the width of the facia, locating plancher level *F*. Measure up from plancher level *F*, 2″, measuring on a plumb line, locating plate level *G*. Plumb line *A* represents the extreme length of the jack rafters to the center line of the valley rafter, so from this length deduct one-half the thickness of the valley measured on the line of the jack rafter, or one-half the diagonal thickness of the valley, *C-D*, Figure 59, which is an enlarged section through *W-W*, Figure 55, and produce plumb line *D*. Square this line across the top edge and locate the center.

The top cuts for these rafters are the same as for the preceding jack rafter, because all rafters on the long common side of the hip and valley rafters are the same pitch. To lay out the top cut so that the jack rafters will fit against the side of the valley rafter at the proper angle measure forward on a level line from plumb line *D*, on the side of the rafter, Figure 60, the

distance *D-1,* Figure 59, and produce plumb line *1,* Figure 60. Connect plumb line *1* through plumb line *D* on the center line as shown at *2,* top view, Figure 60. Cut on line *D* for the cut against the ridge and on bevel *2* on the top edge and plumb line *1* for the cheek cut against the valley rafter on all four rafters. On rafter No. 17 only, cut on line *F* for the plancher level and on lines *G* and *B* for the birdsmouth.

To Lay Out Short Common Rafters.—Before setting the fence and square, the pitch, or rise in inches per foot, must be determined. The run, a constant unit, 12″, remains unchanged. The run of short common rafter No. 6 measured on the layout, Figure 55, measuring from the facia line to the center of the ridge *C, A-C,* is 8″. The total height from the top of the facia to the top of the ridge is 11″. This height is determined by the pitch of the long common rafters as required by the specifications and gives the total height of the roof. Thus, with the total rise 11″ and the total run 8″, find the rise in inches per foot.

Formula:

$$\frac{\textit{Rise in inches}}{\textit{Run in feet}} = \textit{rise in inches per foot.}$$

Working this out as given in the problem, we have: 11/8 x 12/1 = 16 1/2″ = *rise in inches per foot.*

Set the fence and square at 16½″ rise on the blade and 12″ run on the tongue. Mark on the blade for all plumb cuts and on the tongue for all level cuts. Press the fence firmly against the top edge of the stock to be

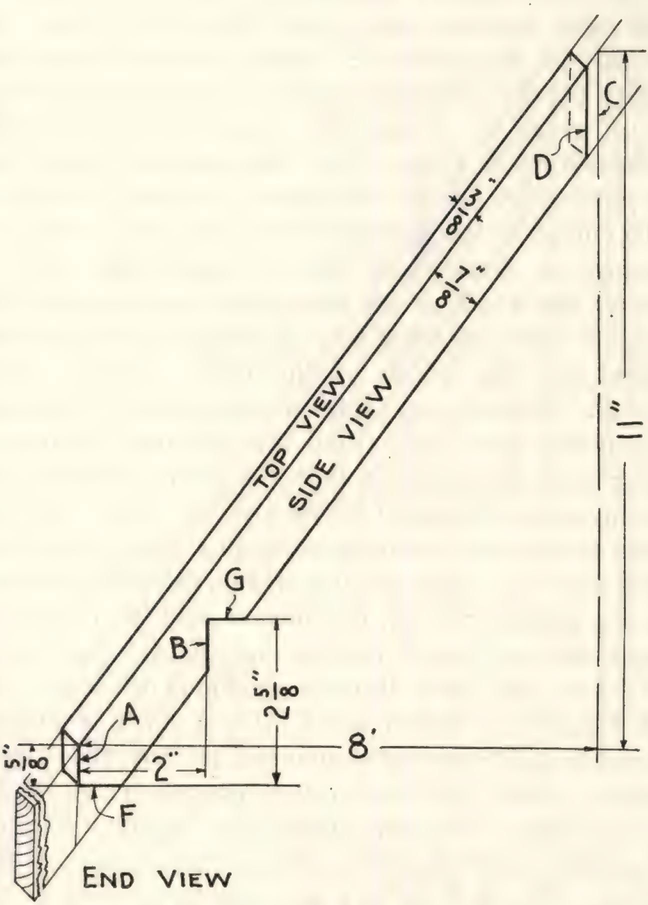


Figure 61.—Developed Length of Short Common Rafter No. C

used and produce the facia line or first plumb line to the extreme left, *A*, Figure 61. Slide the fence to the right and measure on a level line from facia line *A* the run of the rafter, 8″, and produce plumb line *C*, Figure 61, the extreme length of the rafter to the center line of ridge *C*. From this length deduct one-half the thickness of the ridge, 3/16″, and produce plumb line *D*, the cutting length of the rafter against the ridge.

To complete the layout of the lower end of the rafter measure in from facia line *A*, measuring on a level line, 2″, the width of the projection, locating wall line *B*. Measure down on facia line *A* from the top edge of the rafter, 5/8″, the width of the facia, locating plancher level *F*. Measure up from plancher level *F*, measuring on a plumb line, 2 5/8″ (take this distance from the layout, Figure 56, noticing that the short common rafters rest on plates *M* and *O* which are 5/8″ higher than plates *J* and *L* on which the long common rafters rest) locating plate level *G*. Cut on line *A* for the facia, on line *F* for the plancher level, on lines *G* and *B* for the birdsmouth and on line *D* for the cut against the ridge.

To Lay Out Jack Rafters on Short Common Side.—The lengths of jack rafters Nos. 1, 2, 3, 4 and 5 are determined in the same manner as for the preceding common rafter No. 6, since they are a part of the length of it. Take the runs from the layout, Figure 55, measuring from the facia line to the center of the hip rafter. The five rafters are shown developed on the side of a single rafter, Figure 62. In practice these would be laid out separately but are here laid out over one another to save space and to avoid repetition. Press

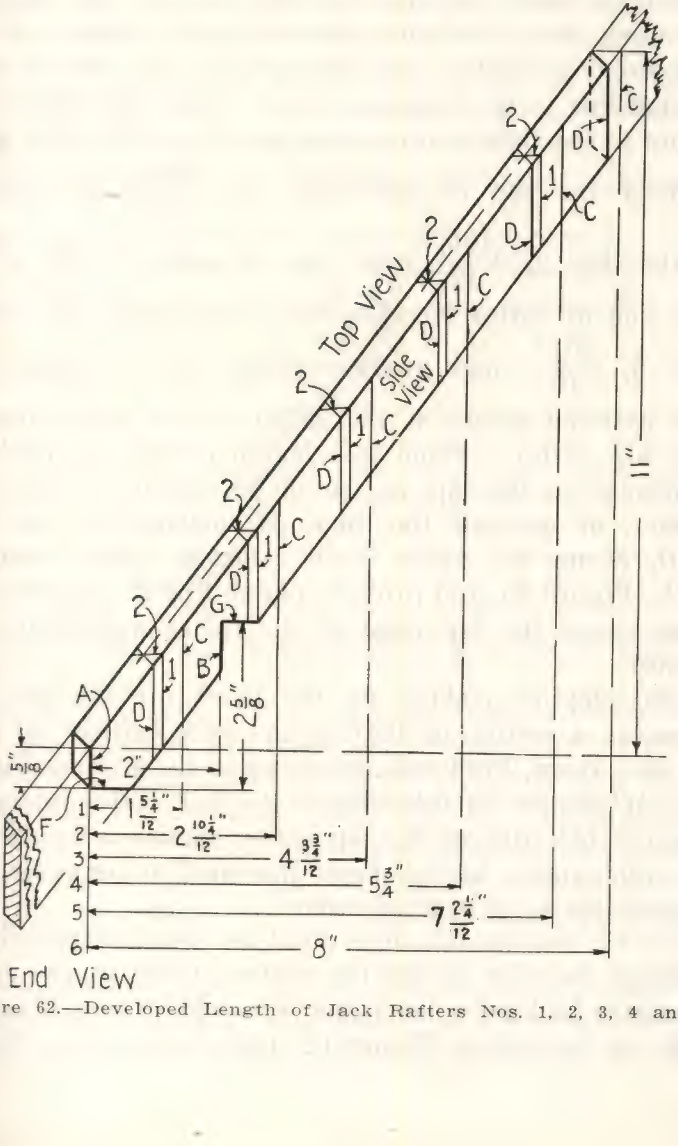


Figure 62.—Developed Length of Jack Rafters Nos. 1, 2, 3, 4 and 5

the fence firmly against the top edge of the stock to be used, using the same figures on the square as for the previous rafter, and produce the facia line or first plumb line to the extreme left, *A*, Figure 62. Slide the fence to the right and measure on a level line from facia line *A* the run of rafter No. 1, $1\frac{5\frac{1}{4}''}{12}$; the run of rafter No. 2, $2\frac{10\frac{1}{4}''}{12}$; the run of rafter No. 3, $4\frac{3\frac{3}{4}''}{12}$ the run of rafter No. 4, 5 3/4″; and the run of rafter No. 5, $7\frac{2\frac{1}{4}''}{12}$; and produce plumb line *C*, Figure 62, the extreme length of the rafter to the center line of the hip rafter. From this length deduct one-half the thickness of the hip, measured on the line of the jack rafter, or one-half the diagonal thickness of the hip, *C-D*, Figure 63, which is an enlarged section through *U-U*, Figure 55, and produce plumb line *D*. Square this line across the top edge of the rafter and locate the center.

To simplify picking up the bevel for the top cut, draw in a section of the hip and jack rafter, full size, on the layout, Figure 55, as shown in the section, Figure 63. Where the outside edge of the jack rafter intersects the outside edge of the hip rafter square a line across at right angles to the center line until it intersects the center line as at *1*, Figure 63.

To lay out the top cut so that the jack rafters will fit against the side of the hip rafter at the proper angle measure back on a level line from plumb line *D* on the side of the rafter, Figure 62, the distance *D-1*, Figure

63, and produce plumb line *1*, Figure 62. Connect plumb line *1* through plumb line *D* on the center line as shown at *2*, top view, Figure 62. The lower end of the rafter is a duplicate of the short common rafter. Measure in from facia line *A*, measuring on a level line, 2″, the width of the projection, locating wall line *B*. Measure

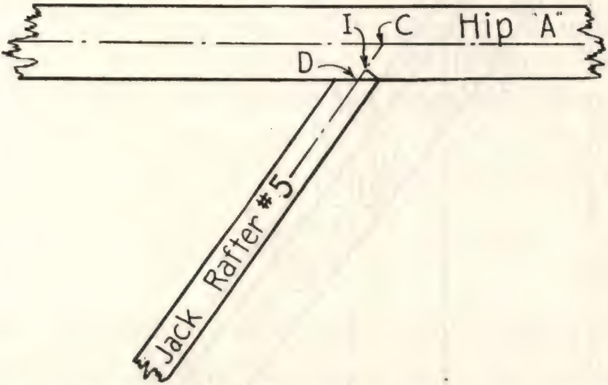


Figure 63.—Full Size Section Through *U-U*, Figure 55, Showing Intersection of Jack and Hip Rafters on the Short Common Side

down on facia line *A* from the top edge of the rafter, ⅝″, the width of the facia, locating plancher level *F*. Measure up from plancher level *F*, measuring on a plumb line, 2⅝″, locating plate level *G*. Cut on line *A* for the facia, on line *F* for the plancher level, on lines *G* and *B* for the birdsmouth and on bevel *2* on the top edge and plumb line *1* for the cheek cut against the hip rafter.

The lengths of jack rafters Nos. 7, 8, 9, 10 and 11 are determined in the same manner as for the preceding jack and common rafters, with the exception that the

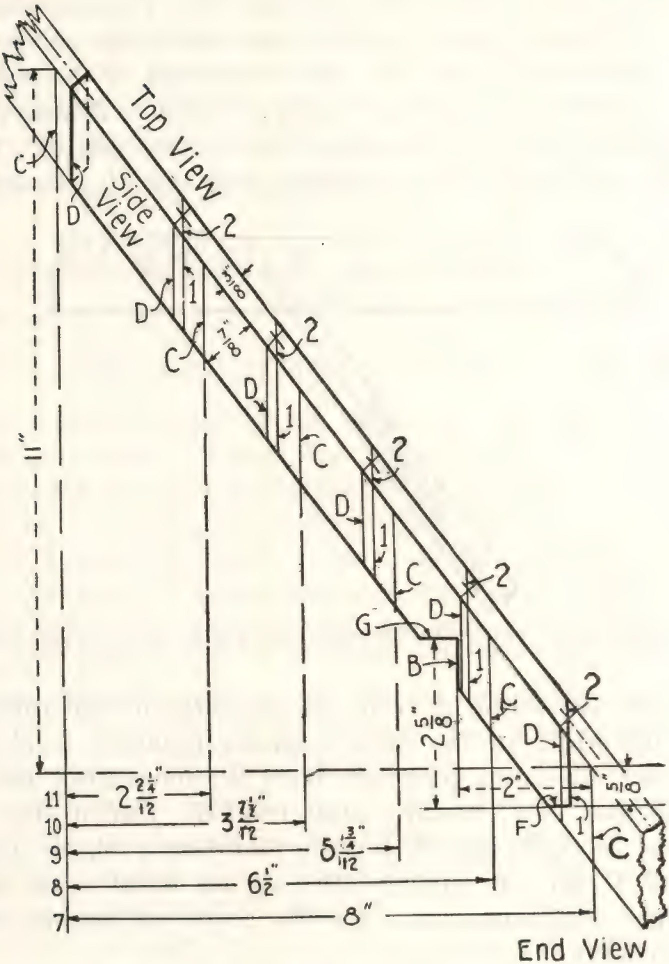


Figure 64.—Developed Length of Jack Rafters Nos. 7, 8, 9, 10 and 11

top and bottom cuts are different. Take the runs from the layout, Figure 55, measuring from the center of the ridge to the center of the valley rafter. The four rafters are shown developed on the side of a single rafter, Figure 64. In practice these would be laid out separately but are here laid out over one another to save space and to avoid repetition. Press the fence firmly against the top edge of the stock to be used and produce the first plumb line to the extreme left, *C*, Figure 64. Slide the fence to the right and measure on a level line the run of rafter No. 7, 8″; the run of rafter No. 8, 6 1/2″; the run of rafter No. 9, $5\frac{3/4''}{12}$; the run of rafter No. 10, $3\frac{7\frac{1}{2}''}{12}$; and the run of rafter No. 11, $2\frac{2\frac{1}{4}''}{12}$; and produce plumb line *C*, Figure 64, the extreme length of the jack rafters from the center line of valley *B* to the center line of ridge *D*. From this length deduct one-half the thickness of the ridge, 3/16″, and produce plumb line *D*, the cutting length of the rafters against the ridge.

The bottoms of all five rafters are beveled to make a fit against the side of the valley. Jack rafters Nos. 7 and 8 also have a bearing on the plate so that the plancher level and birdsmouth must be laid out on common rafter No. 7 and the birdsmouth only on rafter No. 8. To lay out the birdsmouth for rafters Nos. 7 and 8 measure in from plumb line *A*, Figure 64, measuring on a level line, 2″, the width of the projection, locating wall line *B*. Measure down on plumb line *A*, from the top edge of the rafter, ⅝″, the

width of the facia, locating plancher level *F*. Measure up from plancher level *F*, 2⅝″, measuring on a plumb line, locating plate level *G*. Plumb line *A* represents the extreme length of the jack rafters to the center line of the valley rafter, so from this length deduct one-half the thickness of the valley measured on the line of the jack rafters or one-half the diagonal thickness of the valley, *C-D*, Figure 63, which is an enlarged section through *U-U*, Figure 55, and produce plumb line *D*, Figure 64. Square this line across the top edge and locate the center.

The bottom cut for these rafters is the same as for the preceding jack rafters, because all rafters on the short common side of the hip and valley rafters are the same pitch. To lay out the bottom cut so that the jack rafters will fit against the side of the valley rafter at the proper angle measure forward on a level line from plumb line *D*, on the side of the rafters, Figure 64, the distance *D-1*, Figure 63, and produce plumb line *1*, Figure 64. Connect plumb line *1* through plumb line *D* on the center line as shown at *2*, top view, Figure 64. Cut on line *D* for the cut against the ridge and on bevel *2* on the top edge and plumb line *1* for the cheek cut against the valley rafter on all five rafters. On rafters Nos. 7 and 8 cut on lines *G* and *B* for the birdsmouth. On rafter No. 7 cut on line *F* for the plancher level.

To Lay Out the Hip Rafter.—The hip rafter travels the diagonal distance of an oblong with reference to the plates of a building, this being due to the fact that the roof surface on one side of the hip rafter has a greater pitch than the roof surface on the opposite side. The

top edges of all rafters must be in alignment to receive the roof boards. The plancher level should be level throughout the entire roof. The outside lines of the roof that are seen, or the facia lines, must intersect.

Refering to Figure 66, an enlarged section through

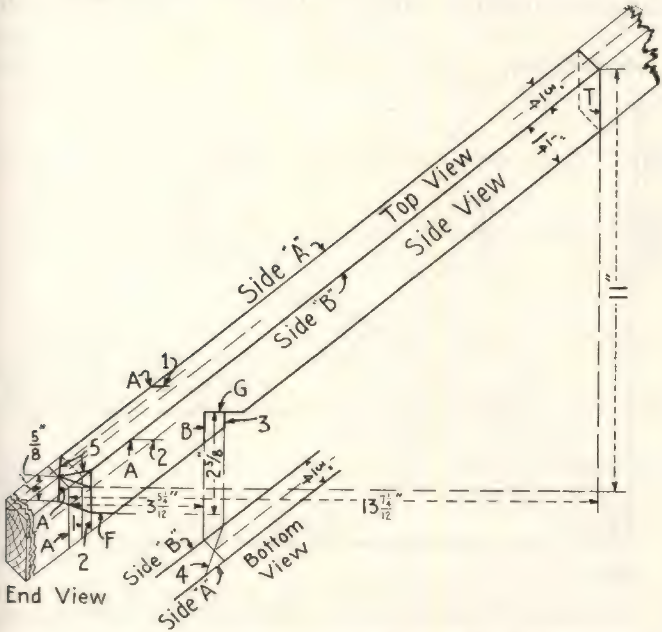


Figure 65.—Developed Length of Hip Rafter

R-R, Figure 55, it will readily be seen that the hip rafter traveling the diagonal distance of an oblong and intersecting with the return corner on the facia line crosses the plate at an angle *A-B,* Figure 66. Hip rafters only cross the corners of a building in roofs of equal pitch where the roof surfaces on both sides of

the hip are the same pitch and the hip travels the diagonal distance of a square or crosses the plates of a building at an angle of forty-five degrees.

In all roofs of equal pitch the run of the hip rafter is 17″ for every foot of run of the common rafter, or the diagonal distance of 12″ and 12″. This rule cannot

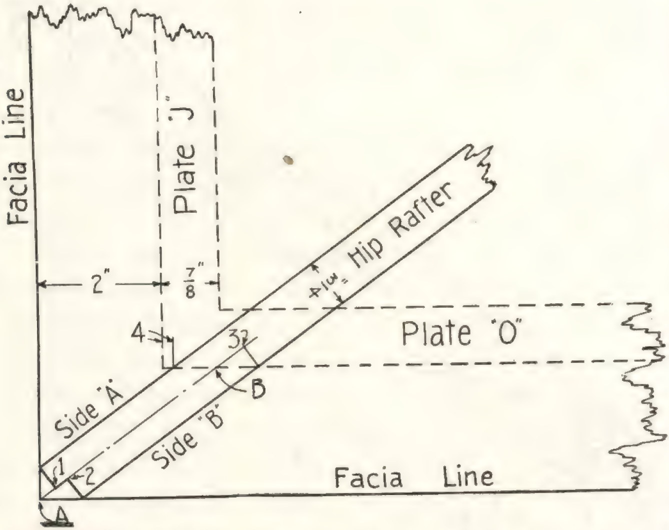


Figure 66.—Full Size Section Through *R-R*, Figure 55, Showing Intersection of the Hip Rafter Plate and Facia Line

apply in roofs of unequal pitch because the hip rafter runs the diagonal distance of an oblong, therefore it becomes necessary to determine the rise in inches per foot of run so that the constant unit of 12″ can be used in framing all the rafters throughout the entire roof.

The total rise of the hip rafter is determined by the

pitch of the long common rafter, which is one-half pitch as noted in the specifications. In a half pitch roof the run and rise are the same. If the common rafter rises 12″ in one foot, it rises 11″ in 11″. The run of the long common rafter being 11″, the total rise must also be 11″, which is the extreme height of the roof.

Take the run of the hip rafter from the layout, Figure 55, measuring from the return on the facia line to the butt joint against the valley rafter, *A-T*, Figure 55, or a run of $13\frac{7\frac{1}{4}}{12}''$. Thus, with a total rise of 11″ and a total run of $13\frac{7\frac{1}{4}}{12}''$, find the rise in inches per foot of run.

$$\frac{\textit{Rise in inches}}{\textit{Run in feet}} = \textit{rise in inches per foot.}$$

Working this out as given in the problem, we have:

$$\frac{132}{13\frac{7\frac{1}{4}}{12}} = 132 \div \frac{163\frac{1}{4}}{12} = 132 \times \frac{12}{163\frac{1}{4}} = 9\frac{8}{12}'' = \textit{rise in inches per foot.}$$

Another way to determine the rise in inches per foot is shown in Figure 67. The same reading should be obtained provided the triangle has been laid out accurately. It is good practice to check up the figures with the steel square to avoid errors. Lay off the run on a horizontal line, $13\frac{7\frac{1}{4}}{12}''$, and the rise on a vertical line, 11″. Connect the two lines with a diagonal line,

forming a triangle. Measure off on the horizontal or level line from the intersection of the horizontal and diagonal lines the unit for one foot run, 12″. Project a vertical or plumb line up from this point until it intersects the diagonal pitch line. The length of this

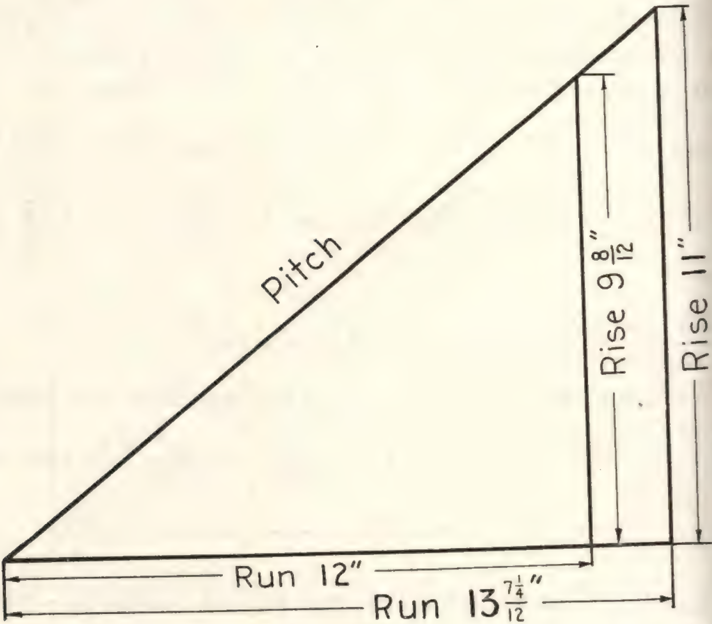


Figure 67.—A Simple Method of Finding the Rise in Inches Per Foot of Run

vertical line from the horizontal base line to the diagonal pitch line is the rise in inches per foot of the rafter, or 9 8/12″.

Set the fence and square at 9 8/12″ rise on the tongue and 12″ run on the blade. Mark on the tongue for all

plumb cuts and on the blade for all level cuts. Press the fence firmly against the top edge of the stock to be used and produce the facia line or first plumb line to the extreme left, *A*, Figure 65. Slide the fence to the right and measure on a level line from facia line *A* the run of the hip, $13\frac{7\frac{1}{4}}{12}''$, and produce plumb line *T*, Figure 65, the extreme length of the rafter forming the butt joint against the valley rafter.

To simplify picking up the bevels for the top cut, the backing and other measurements required in laying out the hip rafter, draw in a section of the hip rafter and plate, full size, on the layout, Figure 55, as shown in the section, Figure 66, which is a section through *R-R*, Figure 55. Where the outside edges of the hip rafter intersect the facia line square lines across at right angles to the center line from both edges of the hip until they intersect the center line as at *1* and *2*, Figure 66. Also, where the outside edge of the hip intersects the wall line, square a line across at right angles to the center line until it intersects the center line as at *3*, Figure 66.

To complete the layout of the lower end of the hip rafter measure in on a level line the diagonal distance of the projection *A-B*, Figure 66, from facia line *A*, on the side of the rafter, or $3\frac{5\frac{1}{4}}{12}''$, locating wall line *B*, Figure 65. Square this line across the bottom edge of the rafter and locate the center point. To make a fit against the wall at the proper angle, measure in on the side of the rafter from wall line *B* the distance *B-3*,

Figure 66, and produce plumb line *3*, Figure 65. Connect plumb line *3* through the center of plumb line *B* on the bottom edge as shown at *4*, bottom view, Figure 65. To complete the birdsmouth measure down on facia line *A* from the top edge of the rafter, $5/8''$, the width of the facia, and produce plancher level F. Measure up from plancher level *F* on a plumb line $2\,5/8''$, locating plate level *G*. The hip rafter crosses plate *O*, the same plate upon which the short common rafters rest; therefore, the distance between plancher level and plate level is the same for short common jack rafters, short common rafters and hip rafter.

To make the return on the facia line at the corner of the building measure back on side *A* of the hip rafter from facia line *A* the distance *A-1*, Figure 66, and produce plumb line *1*, Figure 65. On side *B* measure back on a level line from facia line *A* the distance *A-2*, Figure 66, and produce plumb line *2*, Figure 65. Square facia line *A* across the top edge of the rafter and locate the center point. Connect plumb lines *1* and *2* on the side of the rafter with the center point on the top edge as shown in the top view at *5*, Figure 65. Cut on bevels *5* on the top edge and plumb lines *1* and *2* on the side of the rafter for the facia and on line *F* for the plancher level. On line *G* make a square cut and on bevel *4* and on plumb line *B* on the bottom edge of the rafter make a bevel cut for the birdsmouth, also on line *T* for the butt joint against the valley rafter.

To Back the Hip Rafter.—To determine the amount of stock to be removed in beveling the corners of the hip to bring the center line in alignment with the center

line of the jack and common rafters produce a level line on either side of the hip. On side *A*, from the top edge on this level line, point off the distance *A-1*, Figure 66, as shown at *A-1*, Figure 65. On side *B*, from the top edge on the level line point off the distance *A-2*, Figure 66, as shown at *A-2*, Figure 65. Gauge a line through these points on either side of the rafter and also through the center on the top edge. Remove the corner between these lines as shown in the end view, Figure 65.

To Lay Out the Valley Rafter.—The length of the valley rafter is determined in the same manner as that of the preceding hip rafter. Take the run from the layout, Figure 55, measuring from the return on the facia line to the butt joint against the hip rafter, *A-T*, Figure 14, or $13\frac{7\frac{1}{4}}{12}''$. Press the fence firmly against the top edge of the stock to be used and produce the facia line or first plumb line to the extreme right, *A*, Figure 68. Slide the fence to the left and measure on a level line from facia line *A* the run of the valley, $13\frac{7\frac{1}{4}}{12}''$, and produce plumb line *T*, Figure 68, the extreme length of the rafter forming the butt joint against the hip rafter.

To simplify picking up the bevels, the top cut and other measurements required in laying out the valley rafter, draw in a section of the valley and plate, full size, on the layout, Figure 55, as shown in the section Figure 69, which is a section through *S-S*, Figure 55. Where the center lines of the valley rafter intersect the facia line square a line across at right angles to the

center line, intersecting both edges of the valley as at *A-A,* Figure 69. Also, where the outside edge of the valley intersects the wall line square a line across at right angles to the center line until it intersects the

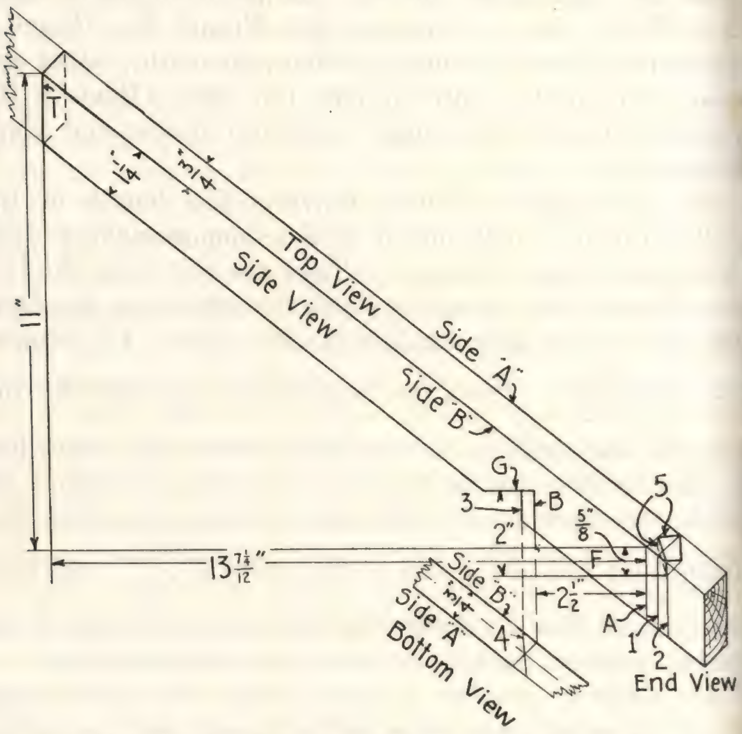


Figure 68.—Developed Length of the Valley Rafter

center line as at *3,* Figure 69.

To complete the layout of the lower end of the valley measure in on a level line from facia line *A* the diagonal distance of the projection *A-B,* Figure 69, on the

side of the rafter, or 2½″, locating wall line *B*, Figure 68. Square this line across the bottom edge of the rafter and locate the center point. To make a fit against

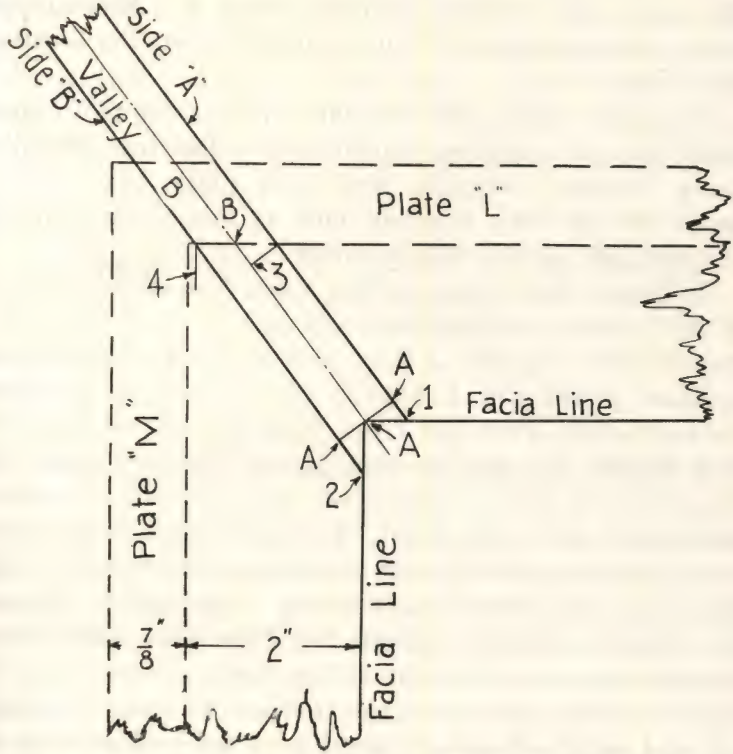


Figure 69.—Full Size Section Through *S-S*, Figure 55, Showing Intersection of the Valley Rafter, Plate and Facia Line

the wall at the proper angle measure in on the side of the rafter from wall line *B* the distance *B-3*, Figure 69, and produce plumb line *3*, Figure 68. Connect plumb

line *3* through the center of plumb line *B* on the bottom edge as shown at *4*, bottom view Figure 68.

To complete the birdsmouth measure down on facia line *A* from the top edge of the rafter $\frac{5}{8}''$, the width of the facia, and produce plancher level *F*. Measure up from plancher level *F* on a plumb line 2″, locating plate level *G*.

The valley rafter crosses plate *L*, the same plate upon which the long common rafters rest; therefore, the distance between plancher level and plate level is the same for the long common jack rafters, long common rafters and for the valley rafter.

To make the return on the facia line at the corner of the building measure forward on side *A* of the valley rafter from facia line *A* the distance *A-1*, Figure 69, and produce plumb line *1*, Figure 68. On side *B* measure forward on a level line from facia line *A* the distance *A-2*, Figure 69, and produce plumb line *2*, Figure 68. Square facia line *A* across the top edge of the rafter and locate the center point. Connect plumb lines *1* and *2* on the side of the rafter with the center point on the top edge as shown in the top view at *5*, Figure 68. Cut on bevels *5* on the top edge and plumb lines *1* and *2* on the side of the valley for the facia. Cut on line *F* for the plancher level. On line *G* make a square cut and on plumb line *B*, bevel *4* on the bottom edge of the rafter a bevel cut for the birdsmouth and on line *T* for the butt joint against the hip rafter.

To Lay Out the Ridges.—The run of the ridges is taken from the layout, Figure 55. For ridge *C* measure the extreme length from the facia line to the intersection

of the center line of the hip and valley rafters and the ridge. From this length deduct one-half the thickness of the valley rafter measured on the line of ridge *C* or one-half the diagonal thickness of the valley, *T-W*, Figure 70, and locate the center on the top edge. Set a bevel square on the layout to the angle formed by the intersection of the valley and ridge. Apply the bevel on the top edge of the ridge and draw a line through the center point thus obtained. For ridge *D*

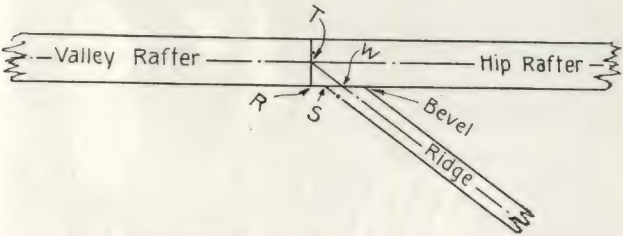


Figure 70.—Full Size Section Through *V-V*, Figure 55, Showing Intersection of the Hip and Valley Rafters and the Ridge

measure the extreme length from the facia line to the intersection of the center line of the hip and valley rafters and ridge. From this length deduct one-half the thickness of the hip rafter measured on the line of ridge *D* or one-half the diagonal thickness of the hip *T-W*, Figure 70, and locate the center point. Set a bevel square on the layout at the angle formed by the intersection of the hip and ridge *D*. Apply the bevel on the top edge of the ridge and draw a line through the center point thus obtained.

To Assemble the Roof.—Assemble the rafters as shown in the elevation, Figure 71. Set up and fasten

the hip and valley rafters first. The center lines of both rafters must intersect at the apex. The exact point of intersection of the hip and valley rafters and the wall line may be determined with reference to the corner or intersection of the two walls as shown in Figures 66 and 69.

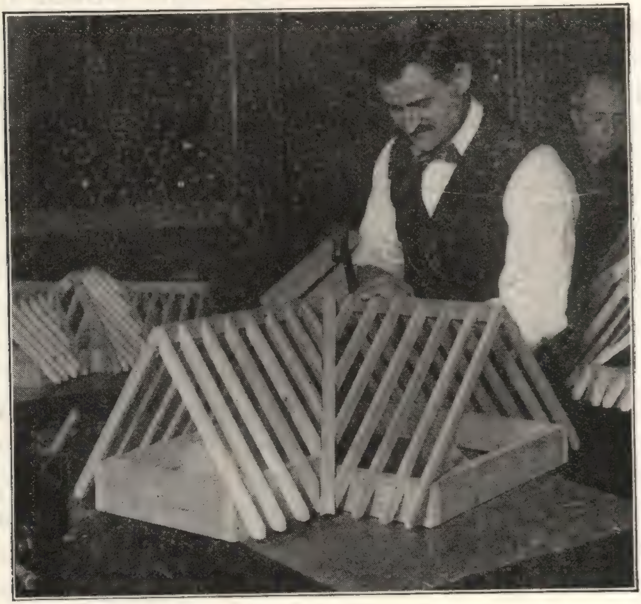


Figure 71.—Elevation of Unequal Pitch Roof, Showing Method of Framing the Rafters

The distance from the corners of the walls to *4* is the distance from the corner of the plate to the outside edge of the hip and valley rafters as they cross the plate. Set up ridges *C* and *D*, securing them in place at the proper height by a pair of common rafters. The top edges of the

ridges are kept flush with the top edges of the common rafters. This drops the ridge out of its normal position, prevents the need for backing the ridge and thus throws the top edge out of alignment with the top edges of the hip and valley rafters.

Both ridges are not on the same level. One ridge is lower than the other owing to the steeper pitch. If the ridges were backed to the pitch of the roof and the lines of the common rafters were continued to the extreme point, all lines would terminate in alignment with the extreme high point formed by the intersection of the hip and valley rafters. The roof boards continue these lines up so that when the roof is completed all roof surfaces are in alignment.

The exact location of the ridges where they intersect the hip and valley rafters may be determined by their location with reference to the butt joint of the hip and valley. Draw in a section of the hip, valley and ridge, full size on the layout, Figure 55, as shown in the section, Figure 70, which is a section through *V-V*, Figure 55. Square a line across at right angles to the center line of the hip at the intersection of the hip and valley rafter, as at *R*, Figure 70, thus establishing the butt joint between the two rafters. The distance *R-S*, Figure 70, gives the distance between the butt joint and the long point of the bevel of the ridge on the side of the rafter.

Development of the Rafters on the Plan.—Figure 72 will serve to illustrate and prove the lengths and bevels and will explain in a graphic way how they are obtained.

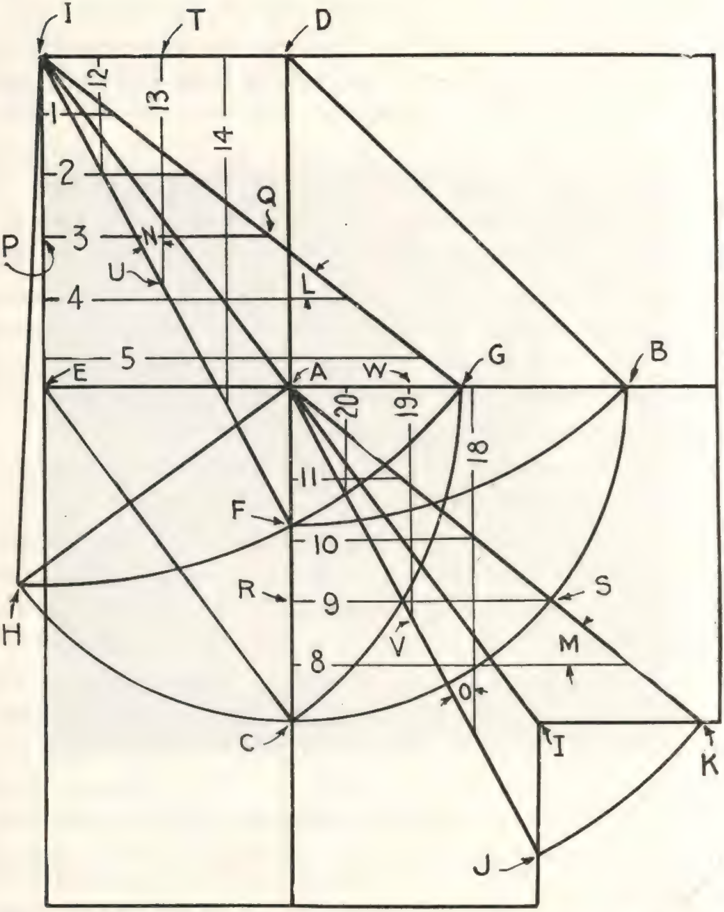


Figure 72.—Graphic Method of Developing the Lengths and Bevels of the Various Rafters Used in Framing an Unequal Pitch Roof

A to *B* is the rise of the long common rafter.

A to *C* is the rise of the short common rafter.

A to *D* is the run of the long common rafter.

A to *E* is the run of the short common rafter.

B to *D* is the length of the long common rafter.

C to *E* is the length of the short common rafter.

D to *F* is the developed length of the long common rafter.

E to *G* is the developed length of the short common rafter.

A to *H* is the rise of the hip and valley rafter.

A to *I* is the run of the hip and valley rafter.

H to *I* is the length of the hip and valley rafter.

F to *I* and *G* to *I* are the developed lengths of the hip rafter.

A to *J* and *A* to *K* are the developed lengths of the valley rafter.

P to *Q* shows the developed lengths of jack rafters 1, 2, 3, 4 and 5.

Angle *L* gives the top cut for jack rafters 1, 2, 3, 4 and 5.

R to *S* shows the developed lengths of jack rafters 8, 9, 10 and 11.

Angle *M* gives the top cut for jack rafters 8, 9, 10 and 11.

T to *U* shows the developed lengths of jack rafters 12, 13 and 14.

Angle *N* gives the top cut for jack rafters 12, 13 and 14.

V to *W* is the developed length of jack rafters 18, 19 and 20.

Angle *O* gives the top cut for jack rafters 18, 19 and 20.

Runs and Lengths of Rafters.—The following table is prepared to assist the student in checking up his work. It is intended that the framer will take his runs from the layout and develop the lengths with the steel square

and fence, using the tables only as a matter of information to give him assurance that he has taken the proper runs and determined the correct lengths of the rafters. The measurements listed in the table are the extreme lengths on the center lines. Make allowances where rafters intersect a ridge, hip or valley rafter for the cutting lengths. It is suggested that the reader frame a model of the roof for practice, building it to the same scale as the layout, 1″ to the foot. In using the table to check the model, read feet as inches; for example, on rafter No. 1, the run would read $1\frac{5\frac{1}{4}}{12}$ and the length $2\frac{5\frac{1}{4}}{12}$″. The square being laid out in twelfths of an inch it is an easy matter to check the work up accurately.

RUNS AND LENGTHS OF RAFTERS USED IN FRAMING ROOF OF UNEQUAL PITCH

Number of Rafters	Quantity of Rafters	Runs	Lengths	Kind of Rafters
1	1	1′ 5¼″	2′ 5¼″	Jack Rafters on Short Common Side
2	1	2′10½″	4′10⅝″	Jack Rafters on Short Common Side
3	1	4′ 3¾″	7′ 4″	Jack Rafters on Short Common Side
4	1	5′ 9″	9′ 9⅜″	
5	1	7′ 2¼″	12′ 2¾″	Jack Rafters on Short Common Side
6	12	8′ 0″	13′ 7¼″	Short Commons
7	1	8′ 0″	13′ 7¼″	Jack Rafters on Short Common Side
8	1	6′ 6″	11′ 0⅝″	Jack Rafters on Short Common Side

RUNS AND LENGTHS OF RAFTERS USED IN FRAMING ROOF OF UNEQUAL PITCH

Number of Rafters	Quantity of Rafters	Runs	Lengths	Kind of Rafters
9	1	5′ 0¾″	8′ 7¼″	Jack Rafters on Short Common Side
10	1	3′ 7½″	6′ 1⅞″	Jack Rafters on Short Common Side
11	1	2′ 2¼″	3′ 8⅝″	
12	1	2′ 9″	3′10⅝″	Jack Rafters on Long Common Side
13	1	5′ 6″	7′ 9⅜″	Jack Rafters on Long Common Side
14	1	8′ 3″	11′ 8″	
15	1	11′ 0″	15′ 6⅝″	Jack Rafters on Long Common Side
16	10	11′ 0″	15′ 6⅝″	Long Commons
17	1	11′ 0″	15′ 6⅝″	Jack Rafters on Long Common Side
18	1	8′ 3″	11′ 8″	Jack Rafters on Long Common Side
19	1	5′ 6″	7′ 9⅜″	
20	1	2′ 9″	3′10⅝″	Jack Rafters on Long Common Side
A	1	13′ 7¼″	17′ 6″	Hip Rafter
B	1	13′ 7¼″	17′ 6″	Valley Rafter
C	1	17′ 0″	17′ 0″	Ridge
D	1	14′ 0″	14′ 0″	Ridge

Figures to use on the steel square:

Long common rafters, 12″ on tongue and 12″ on blade. Mark on the tongue for plumb cut and on blade for level cut.

Short common rafters, 12″ on tongue, 16½″ on blade. Mark on tongue for level cut and on blade for plumb cut.

Hip and valley rafters 9 8/12″ on tongue and 12″ on blade. Mark on tongue for plumb cut and on blade for level cut.

PART 1.

SOLID GEOMETRY.

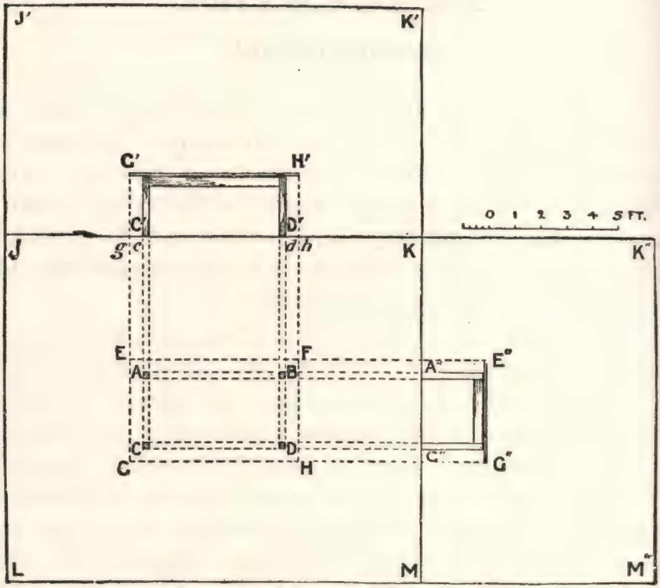
INTRODUCTORY.

In the first volume of Modern Carpentry I gave a short treatise on plain or Carpenters' Geometry, which I trust the student has mastered, and thus prepared himself for a higher grade in the same science, namely, **Solid Geometry**: and to this end, the following treatise has been selected, as being the most simple and the most thorough available.

Solid geometry is that branch of geometry which treats of solids—i.e., objects of three dimensions (length, breadth and thickness). By means of solid geometry these objects can be represented on a plane surface, such as a sheet of paper, in such a manner that the dimensions of the object can be accurately measured from the drawing by means of a rule or scale. The "geometrical" drawings supplied by the architect or engineer for the builder's use are, with few exceptions, problems in solid geometry, and therefore a certain amount of knowledge of the subject is indispensable, not only to the draughtsman who prepares the drawings, but also to the builder or workman who has to interpret them.

As the geometrical representations of objects consist entirely of lines and points, it follows that if projections of lines and points can be accurately drawn,

the representation of objects will present no further difficulty. A study of lines and points, however, is somewhat confusing, unless the theory of projection has first been grasped, and for this reason the subject will be introduced by a simple concrete example,



Vertical Projections (or Elevations) and Horizontal Projection (or Plan) of a Table in the Middle of an Oblong Room

Fig. 1.

such, as a table standing in the middle of a room. The four legs rest on the floor at A, B, C, and D (Fig. 1), and the perpendiculars let fall from the corners of the table-top to meet the floor at E, F, G, and H. The oblong E F G H represents the horizontal projection or "plan" of the table-top; the small squares at A,

B, C, and D represent the plan of the four legs, and the lines correcting them represent the plan of the frame work under the top. The large oblong J K L M is a plan of the room.

The plan or horizontal projection of an object is therefore a representation of its horizontal dimensions —in other words, it is the appearance which an object presents when every point in it is viewed from a position vertically above that point.

In a similar manner an elevation or vertical projection of an object is a representation of its vertical dimensions, and also, it should be added, of some of its horizontal dimensions,—i. e., it is the appearance which an object presents when every point in it is viewed from a position exactly level with that point, all the lines of sight being parallel both horizontally and vertically. Thus, the front elevation of the table (or the vertical projection of the side G H) will be as shown at G′ H′ C′ D′, and the vertical projection of the side J K of the room will be J K J K. The vertical projection of the end of E G of the table will be as shown E″ G″ A″ C″ and of the end K M of the room will be K″ M″ K M; the drawing must be turned until the line K M is horizontal, for these and projections to be properly seen.

By applying the scale to the plan, we find that the length of the table-top is six and a half feet, the breadth 4 feet, and the distance of the table from each wall 4¾ feet. From the **front elevation** we can learn the height of the table, and also give its length and distance from the end walls of the room. From the **end elevation** we can ascertain the breadth of the table and

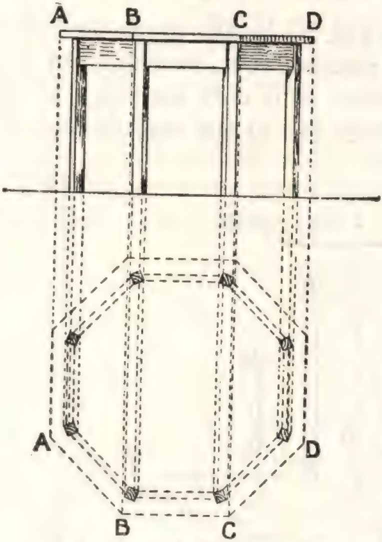
its distance from the sides of the room, as well as its height.

To make the drawing clearer, let us imagine that the walls of the room are of wood and hinged at the level of the floor. On the wall J K draw the front elevation of the table and then turn the wall back on its hinges until it is horizontal,—i. e., in the same plane as the floor. Proceed in a similar manner with the end K M, and we get the three projections of the room and table on one plane, as shown in the diagram. To avoid confusion the end elevation will not be further considered at the present.

It will be seen that the line J K represents the angle formed by the wall and floor,—in other words, it represents the intersection of the vertical and horizontal "planes of projection," it is known as "the line of intersection," or "the ground line." If a line is let fall from G′ perpendicular to J K, the two lines will meet at G, and they will be in the same straight line. Similarly, the perpendiculars H′ h and h H are in the same straight line. Lines of this kind perpendicular to the planes of projections are known as "projectors" and are either horizontal or vertical G′ g and H′ h are vertical projectors; G g, C c, D d, and H h are horizontal projectors.

Vertical projectors are not always parallel to one of the sides of the object represented, or, if parallel to one side, are not parallel to other sides which must be represented; thus, a vertical projector or "elevation" of an octagonal object, if parallel to one of the sides of the octagon, must be oblique to the two adjacent sides. In Fig. 2 an octagonal table is shown. The

plan must first be drawn, and from the principal points of the plan projectors must be drawn perpendicular to the vertical plane of the projection, until they cut the ground line, and from this perpendiculars must be erected to the height of the several parts of



Plan and Elevation of an Octagonal Table

Fig. 2.

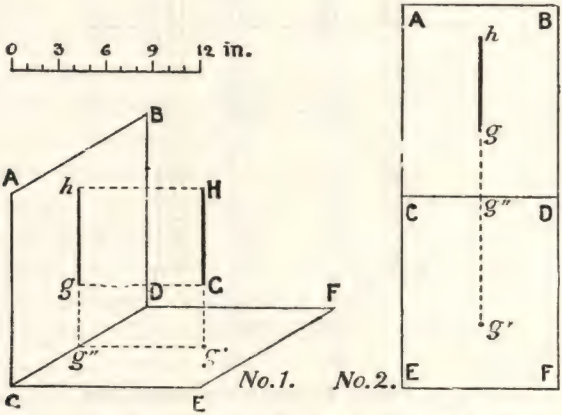
the table. The elevation can then be completed without difficulty. The side B C of the table is parallel to the vertical plane of projection, but the adjacent sides A B and C D are oblique.*

*A distinction must be made between "perpendicular" and "vertical." The former means, in geometry, a line or plane at right angles to another line or plane, whether these are horizontal, vertical or inclined; whereas a vertical line or plane is always at right angles to a horizontal line or plane. The spirit-level gives the horizontal line or plane, the plumb-rule gives the vertical.

2. POINTS, LINES, AND PLANES.

I. To determine the position and length of a given straight line, parallel to one of the planes of the projection.

Let G H (Fig. 3) be the given straight line. To determine its position (i e., in regard to horizontal and vertical planes), it is only necessary to determine the position of any two of the extreme points.



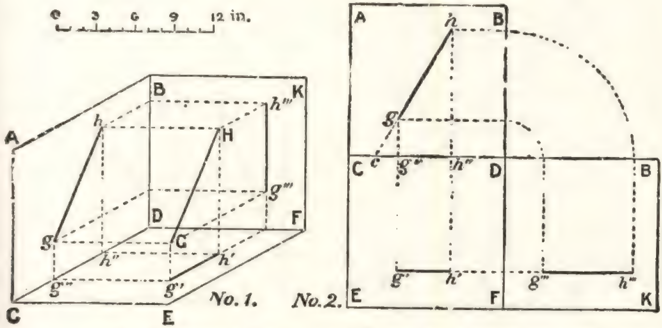
·No. 1. Perspective View. No. 2. Geometrical Projections Horizontal and Vertical

Fig 3.

Let A B C D be a vertical plane parallel to the given line, and C D E F a horizontal plane. The vertical projection or elevation of the line is represented by the line h g, and the horizontal projection or plan by the point g′, the various projections being shown by dotted lines. The given line is proved to be vertical, because

its horizontal projection is a point; its length as measured by the scale, is 6 inches; its height (g g″) above the line of intersection C D is 4 inches; and its horizontal distance (g′ g″) from the same line is 8 inches.

If the illustrations are turned so that C D E F become a vertical plane, and A B C D the horizontal plane then G H will be horizontal line, because one of its vertical projections is a point. Other vertical projections of the line can be made,—as, for example, a side elevation,—in which the projection will appear as a line and not a point, but a line must be horizontal if any vertical projection of it is a point.



-No. 1. Perspective View. No. 2. Vertical and Horizontal Projections

Fig. 4.

Let the given line G H (Fig. 4) be parallel to the vertical plane, but inclined to the horizontal plane. Then g h will be a vertical projection, and g′ h′ its horizontal projection or plan. By producing h g till it cuts C D at c, it will be found that the given line is inclined at an angle of 60° to the horizontal plane; its length, as measured by the scale along the vertical

projection g h, is 8 inches; the height of G above the horizontal plane (measured at g g″) is 3 inches, and the height of H (measured at h h″) is 9¾ inches.

II. To determine the length of a given straight line which is oblique to both planes of projection.

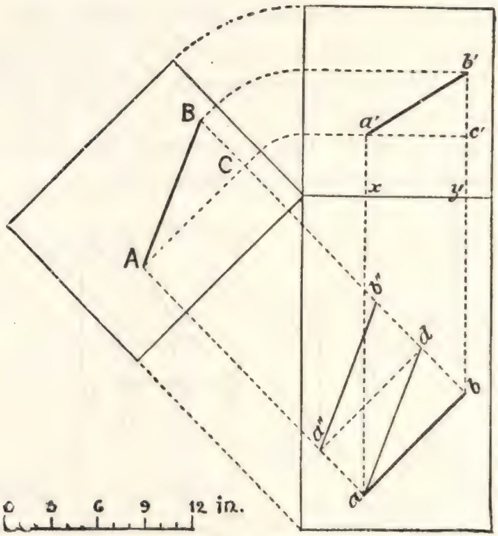
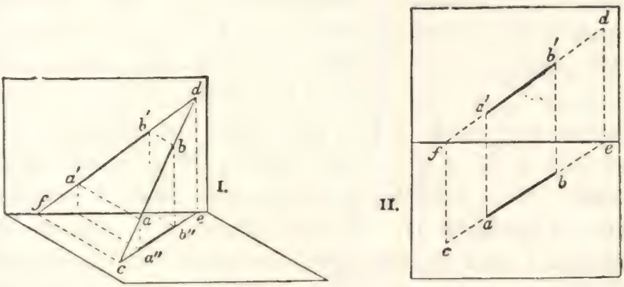


Fig. 5.

Let a b (Fig. 5) be the horizontal projection and a′ b′ the given vertical projection of the given line. Draw the projection A B on a plane parallel to a b in the manner shown. From this projection the length of the given line will be found (by applying the scale) to be 10 inches. The height C B is of course equal to the height c′ b′, and the horizontal measurement A C is equal to the horizontal projection a b, and the angle

A C B is a right angle. It follows therefore that, if from b the line b d is drawn perpendicular to a b and equal to the height c′ b′, the line joining a d will be the length of the given line. To avoid drawing the horizontal line a′ c′ the height of a′ and b′ above x y are usually set up from a and b as at a″ and b″, the line a″ b″ is the length of the given line.*

III. The projections of a right line being given, to find the points wherein the prolongation of that line would meet the planes of projection.



-I. Perspective View. II. Vertical and Horizontal Projections

Fig. 6.

Let a b and a′ b′ (Fig. 6, II) be the given projection of the line A B. In the perspective representation of the problem it is seen that A B, if prolonged, cuts the horizontal plane in c, and the vertical plane in d, and the projections of the prolongation become c e and f d. Hence, if a b, a′ b′ (Fig. 6, II) be the projections

*The application of this problem to hips is obvious. Suppose that *a b* is the plan of a hip-rafter, and *a′ b′* an elevation, the length of the rafter will be equal to *a d* or A B.

of A B, the solution of the problem is obtained by producing these lines to meet the common intersection of the planes in f and e, and on these points raising the perpendiculars f c and e d, meeting a b produced in c and a′ b′ produced in d; c and d are the points sought.*

IV. If two lines intersect each other in space, to find from their given projections the angles which they make with each other.

Let a b, c d, and a′ b′ c′ d′ (Fig.7) be the projections of the lines. Draw the projectors e′ f′ f′ e′, perpendicular to the line of intersection a′ c′, and produce it indefinitely towards E″; from e draw indefinitely, e E′ perpendicular to the line e′ f, and make e E′ equal to f″ e, and draw f E′. From f as a centre describe the arc E″ g E″, meeting e f produced in E″, and join a E″ c E″. The angle a E″ c is the angle sought. This problem is little more than a development of problem II. If we consider e f, e′f′, as the horizontal and vertical projections of an imaginary line lying in the same plane as a e and c e, we find the length of this line by problem II to be f E′; in other words f E′ is the true altitude of the triangle a e c, a′ e′ c′. Construct a triangle on the base a e with an altitude f E′ equal to f E′, and the problem is solved. The practical application of this problem will

*The points *d* and *c* are known respectively as the vertical and horizontal "traces" of the line A B, the trace, of a straight line on a plane being the point in which the straight line, produced if necessary, meets or intersects the plane. A horizontal line cannot therefore have a horizontal trace, as it cannot possibly, even if produced, meet or intersect the horizontal plane; for a similar reason, a vertical line cannot have a vertical trace.

be understood if we imagine a e c to be the plan and a′ e′ c′ the elevation of a hipped roof; f E′ gives us the length and slope of the longest common rafter or spar, and E″ c is a true representation of the whole hip, i. e., on a plane parallel to the slope of the top. It will

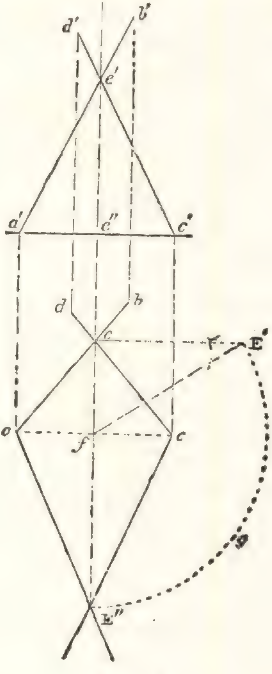
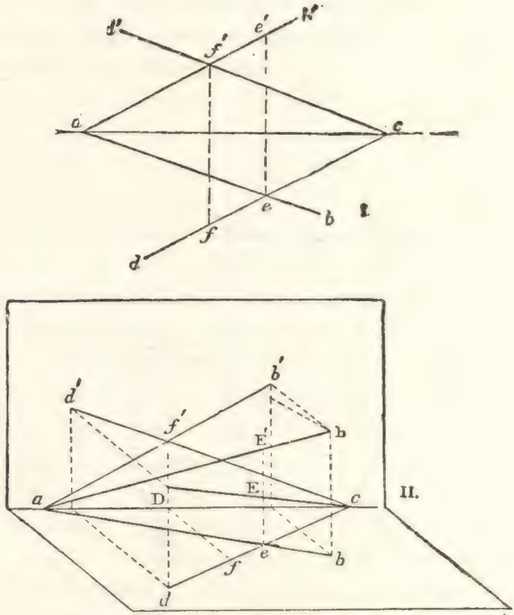


Fig. 7.

be observed that the two projections (e and e′) of the point of intersection of the two lines are in a right line perpendicular to the line of intersection of the planes of projection. Hence this corollary.—**The pro-**

jections of the point of intersections of two lines which cut each other in space are in the same right line perpendicular to the common intersection of the planes of projection. This is further illustrated by the next problem.



I. Vertical and Horizontal Projections. II. Perspective View

Fig. 8.

V. To determine from the projection of two lines which intersect each other in the projections, whether the lines cut each other in space or not.

Let a b, c d, a b′, c d′ (Fig. 8, I) be the projections of the lines. It might be supposed, as their projections

intersect each other that the lines themselves intersect each other in space, but on applying the corollary of the preceding problem, it is found that the intersections are not in the same perpendicular to the line of intersection a c of the planes of projection. This is represented in perspective in Fig. 8, II. We there see that the original lines a B c D do not cut each other, although their projections a b, c d, a b′, c d′, do so. From the point of intersection e raise a perpendicular to the horizontal plane, and it will cut the original line c D, in E, and this point therefore belongs to the line c D, but c belongs equally to a B. As the perpendicular raised on e passes through E on the line c D, and through E on the line a B, these points E E′ cannot be the intersection of the two lines, since they do not touch; and it is also the same in regard to f f. Hence, when two right lines do not cut each other in space, the intersections of their projections are not in the same right line perpendicular to the common intersection of the planes of projection.

VI. To find the angle made by a plane with the horizontal plane of projection.

Let a b and a c, Fig. 9, be the horizontal and vertical traces of the given plane, i. e., the lines on which the given plane would, if produced, cut the horizontal and vertical planes of projection. Take any convenient point d in a b, and from it draw d e perpendicular to a b, and cutting the line of intersection x y in e, from e draw e d perpendicular to x y and cutting a c in d′. The angle made by the given plane with the horizontal plane of projection is such that, with a base d e, it has a vertical height e d′. Draw such an

angle on the vertical plane of projection by setting off from e the distance e d″ equal to e d, and joining d′ d″. The angle d′ d″ e is the angle required.*

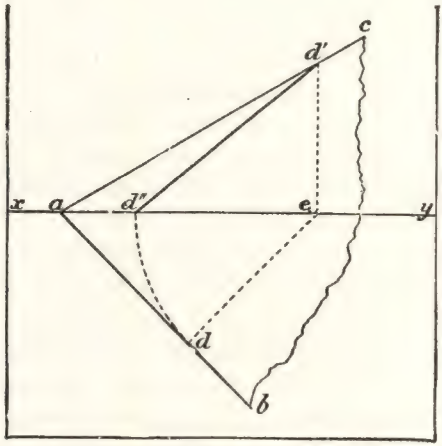


Fig. 9.

VII. The traces of a plane and the projections of a point being given, to draw through the point a plane parallel to the given plane.

In the perspective representation (Figs. 10 and 11) suppose the problem solved, and let B C be the given

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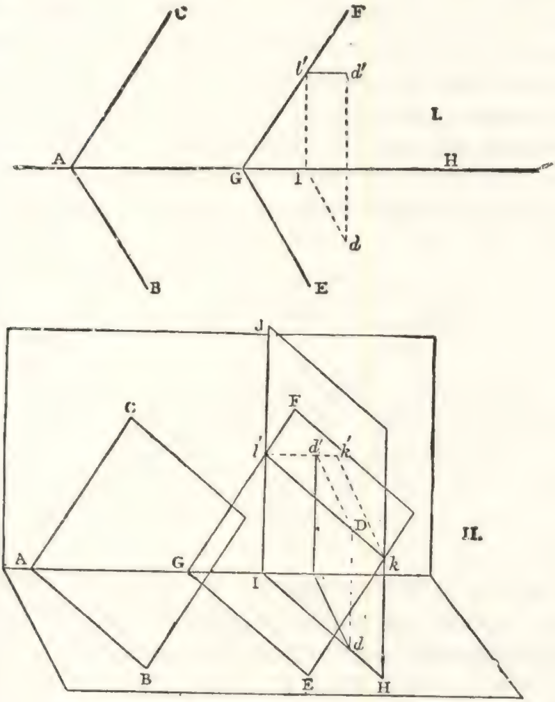
*The angle made by a plane with the vertical plane of projection can be found in a similar manner. If we imagine the part above *x y* in Fig. 9 to be the horizontal projection and the part below *x y* to be the vertical projection—in other words, if Fig. 9 is turned upside down—*a b* becomes the vertical trace and *a c* the horizontal trace, and the angle *d′ d″ e* is the angle made by the given plane with the vertical plane of projection.

plane, and A C, A B its vertical and horizontal traces, and E F a plane parallel to the given plane, and G F G E its traces. Through any point D, taken at pleasur,



I. Vertical and Horizontal Projections. II. Perspective View

Fig. 10.

on the plane E F, draw the vertical plane H J, the horizontal trace of which, I H, is parallel to G E. The plane H J cuts the plane E F in the line k l′, and its vertical trace G F in l′. The horizontal projection

of k′ l′ is H I, and its vertical projection k′ l′ ; and as the point D is in k l′, its horizontal and vertical projections will be d and d′. Therefore, if through d be traced a line d l, parallel to A B, that line will be the horizontal projection of a vertical plane passing through the original point D; and if an l be drawn the indefinite perpendicular L″ l′, and through d′, the vertical projection of the given point, be drawn the horizontal line d′ l′, cutting the perpendicular in l′, then the line F G drawn through l parallel to A C, will be the vertical trace of the plane required; and

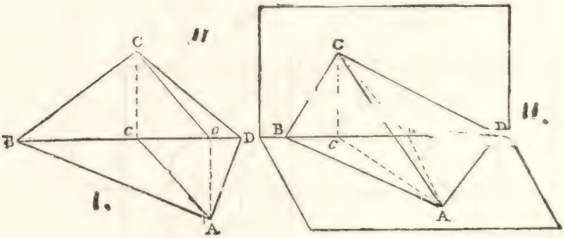


Fig. 11.

the line G E drawn parallel to A B, its horizontal trace. Hence, **all planes parallel to each other have their projections parallel, and reciprocally.** In solving the problem, let A B, A C (Figs. 10, I) be the traces of the given plane, and d d the projections of the given point. Through d draw d l parallel to A B, and from I draw I l′ perpendicular to A H. Join d d′ and through d′ draw d′ l′ parallel to the line of intersection A H. Then F l′ G drawn parallel to A C, and G E parallel to A B, are the traces of the required plane.

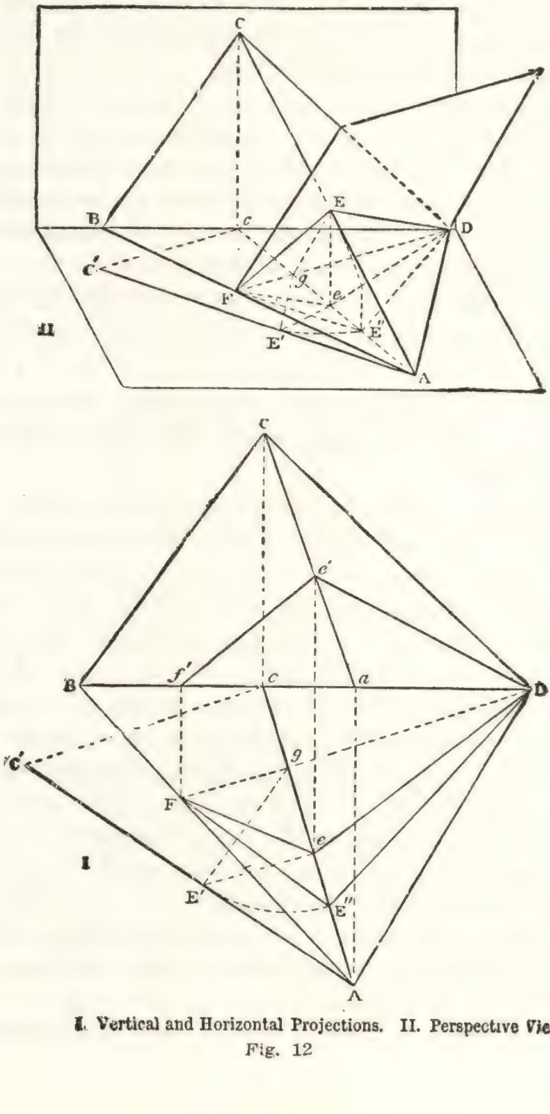
VIII. The traces A B, B C, and A D, D C, of two planes which cut each other being given, to find the projections of their intersections.

The planes intersect each other in the straight line A C (Fig.II, 11), of which the points A and C are the traces, since in these points this line intersects the planes of projection. To find these projections, it is only necessary to let fall on the line of intersection in Fig. II, 1, the perpendiculars A a, C c, from the points A and C, and join A c, C a. A c will be the horizontal projection, and C a the vertical projection of C A, which is the line of intersection or arris of the planes.

IX. The traces of two intersecting planes being given, to find the angle which the planes make between them.

The angle formed by two planes is measured by that of two lines drawn from the same point in their intersection (one along each of the planes), perpendicular to the line formed by the intersection. This will be better understood by drawing a straight line across the crease in a double sheet of note-paper at right angles to the crease; if the two leaves of the paper are then partly closed so as to form an angle, we have an angle formed by two planes, and this angle is the same as that formed by two lines which have been drawn perpendicular to the line of intersection of the two planes. These lines in effect determine a third plane perpendicular to the arris. If, therefore, the two planes are cut by a third plane at right angles to their intersection the solution of the problem is obtained.

On the arris A C (Fig. 12, 11) take at pleasure any

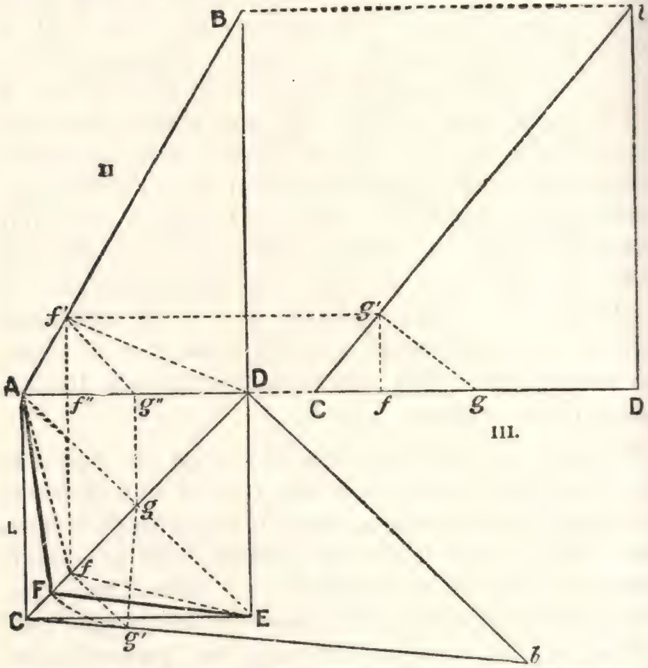


I. Vertical and Horizontal Projections. II. Perspective View
Fig. 12

point E, and suppose a plane passing through that point cutting the two given planes perpendicular to the arris. There results from the section a triangle D E F, inclined to the horizontal plane, and the angle of which, D E F, is the measure of the inclination of the two planes. The horizontal projection of that triangle is the triangle D e F, the base of which, F D, is perpendicular to A c (the horizontal projection of the arris A C), and cuts it in the point g, and the line E g is perpendicular to D F. The line g E is necessary perpendicular to the arris A C, as it is in the plane D E F, and its horizontal projection is g e. Now, suppose the triangle D E F turned on D F as an axis, and laid horizontally, its summit will then be at E″, and D E″ F is the angle sought. The perpendicular g E is also in the vertical triangle A C c, of which the arris is the hypothenuse and the sides A c, C C are the projections. This description introduces the solution of the problem.

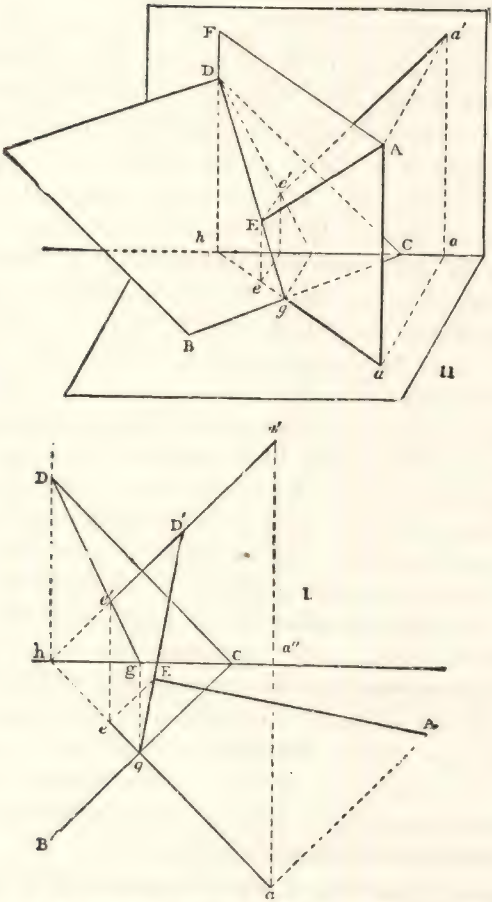
Through any point g (Fig. 12, 1) on the line A c, the horizontal projection of the arris or line of intersection of the two planes, draw F D perpendicular to A c; on A c (which for the moment must be considered as a "line of intersection" or "ground line" for a second vertical projection) describe the vertical projection of the arris by drawing the perpendicular c C, and then joining A C′. A C gives the true length and inclination of the arris. From g draw g E′ perpendicular to A C′, and meeting it in E′; from E′ let fall a perpendicular E e′ or A c, meeting A c in e. F e D is the horizontal projection of the triangle F E D (see No. 11) and from this the vertical projection

f′ e′ D can be drawn as shown. We have now obtained the vertical and horizontal projections of two intersecting lines, namely, F e, e D, and f′ e′, e′ D, and by problem (4) the triangle which they make with each other can be found. It will be seen that g E′ is the



I. Horizontal Projection. II. Vertical Projection on Plane A D.
III. Vertical Projection on Plane C D
Fig. 13.

true altitude of the triangle f′ e′ D, as e E is equal to e′ e. Set off therefore from g towards A a distance g E equal to g E, and join F E, E″ D; F E″ D is the angle made by the two intersecting planes.



I. Vertical and Horizontal Projections. II. Perspective View

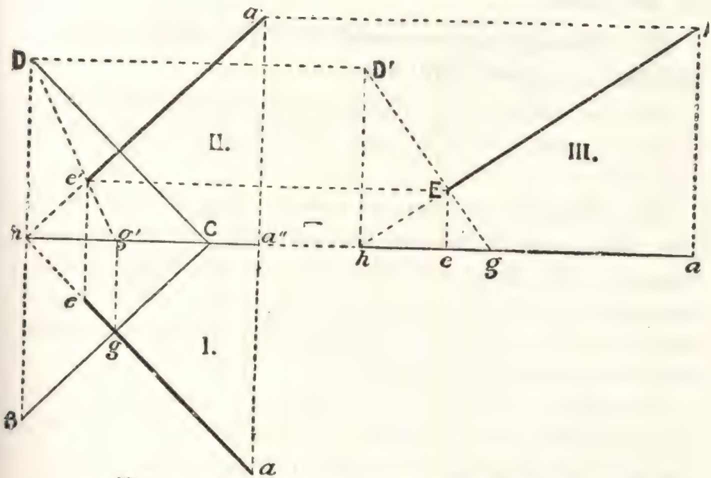
Fig. 14.

X. Through a given point to draw a perpendicular to a given plane.

Let a and a′ (Fig. 14, II.) be the projections of the given point, and B C, C D the horizontal and vertical traces of the given plane. Suppose the problem solved, and that A E is the perpendicular drawn through the A to the plane B D, and that its intersection with the plane is the point E. Suppose also a **vertical** plane a F to pass through A E′, this plane would cut B D in the line g D, and its horizontal trace a h would be perpendicular to the trace B C. In the same way a′ e′, the vertical projection of A E, would be perpendicular to C D, the vertical trace of the plane B D. Thus we find that if a line a h is drawn from a, perpendicular to B C, it will be the horizontal trace of the plane in which lies the required perpendicular A E, and h F will be the vertical trace of the same plane. From a′, draw upon C D an indefinite perpendicular, and that line will contain the vertical projection of A E, as a h contains its horizontal projection. To find the point of intersection of the line A E with the given plane, construct the vertical projection g D of the line of intersection of the two planes, and the point of intersection of that line with the right line drawn through a′, will be the point sought. If from that point a perpendicular is let fall on a h, the point e will be the horizontal projection of the point of intersection E.

In Fig. 15, 1, let B C, C D be the traces of the given plane, and a, a′ the projections of the given point. From the point a, draw a h perpendicular to B C; a h will be the horizontal projection of a plane passing

vertically through a, and cutting the given plane. On a h as "ground line" draw a vertical projection as follows: From a, draw a A perpendicular to a g, and make it equal to a″ a′; from h draw h D′ perpendicular to h a, and make h D′ equal to h D; draw g D, which will be the section of the given plane by



I. Horizontal Projection. II. Vertical Projection on Plane parallel to $h a''$. III. Vertical Projection on Plane parallel to $h a$

Fig. 15.

a vertical D g, and the angle h g D′ will be the measure of the inclination of the given plane with the horizontal plane; there is now to be drawn, perpendicular to this line, a line A E through A, which will be the vertical projection on a h of the line required. From the point of intersection E let fall upon a h a

perpendicular, which will give e as the horizontal projection of E. Therefore a e is the horizontal projection of the required perpendicular, and a′ e′ its vertical projection on the original "ground line" h a″. It follows from this problem that—**Where a right line in space is perpendicular to a plane, the projections of that line are respectively perpendicular to the traces of the plane.**

XI. Through a given point to draw a plane perpendicular to a given right line.

Let a, a′ (Fig. 16, 1) be the projections of the given point A, and b c, b′ c′ the projections of the given line B C.

The foregoing problem has shown that the traces of the plane sought must be perpendicular to the projections of the line, and the solution of the problem consists in making to pass through A, a vertical plane A f (Fig. 16, 11), the horizontal projection of which will be perpendicular to b c.

Through a (Fig. 16, 1) draw the projection a f perpendicular to b c. From f raise upon K L the indefinite perpendicular f f, which will be the vertical trace of the plane a f f perpendicular to the horizontal plane, and passing through the original point A (in No. 11). Then draw through a in the vertical projection a horizontal line, cutting f f in f, which point should be in the trace of the plane sought; and as that plane must be perpendicular to the vertical projection of the given right line draw through f a perpendicular to b c, and produce it to cut K L in G. This point G is in the horizontal trace of the plane sought. All that remains therefore, is from G to draw

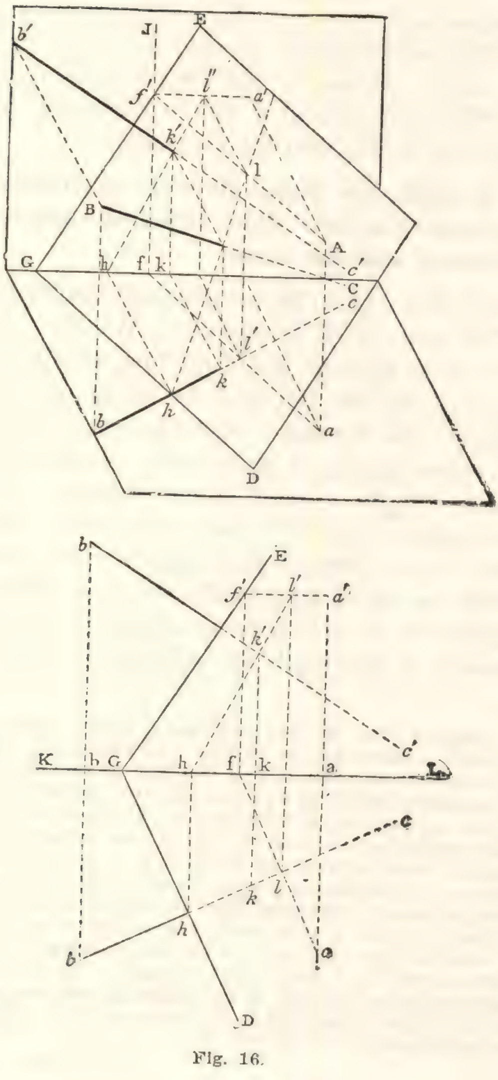


Fig. 16.

G D perpendicular to b c. If the projections of the straight line are required, proceed as in the previous problem, and as shown by the dotted lines; the plane will cut the given line at k in the horizontal projection, and at k in the vertical projection.*

XII. A right line being given in projection, and also the traces of a given plane, to find the angle which the line makes with the plane.

Let A B (Fig. 17, 11) be the original right line intersecting the plane C E in the point B. If a vertical plane a B pass through the right line, it will cut the plane C E in the line f B, and the horizontal plane in the line a b. As the plane a B is in this case parallel to the vertical plane of projection, its projection on that plane will be a quadrilateral figure a b of the same dimensions, and f B contained in the rectangle will have for its vertical projection a right line D b, which will be equal and similar to f B. Hence the two angles a b D, A B f, being equal, will equally be the measure of the angle of inclination of the right

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*The diagram will be less confusing if the projection on *a h* is drawn separately, as in Fig. 16, where I is the horizontal projection or plan, II the vertical projection or elevation on a plane parallel to *ha″*, and III the vertical projection or elevation on a plane parallel to *h a*. To draw No. III draw first the ground-line *h a* equal to *h a* on No. I, and mark on it the point *g;* from *h* draw the vertical *h* D′ equal to *h* D, and from *a* draw the vertical *a* A equal to *a″ a′;* join D′ *g* and A *h*, and from the point of intersection E let fall a perpendicular on *h a*, cutting it in e. A E is the actual length and inclination of the required line, and *a e* its horizontal length. Transfer the length *a e* to No. I, and from *e* draw *e e′* perpendicular to *h a″* and cutting *a′ h* in *e′*. If the drawing has been correctly made, a line from E parallel to the ground-line *h a″* will also intersect *a′ h* in *e′*.

line A B to the plane C E. Thus the angle a b D (Fig. 17, 1), is the angle sought.

This case presents no difficulty; but when the line is in a plane which is not parallel to the plane of

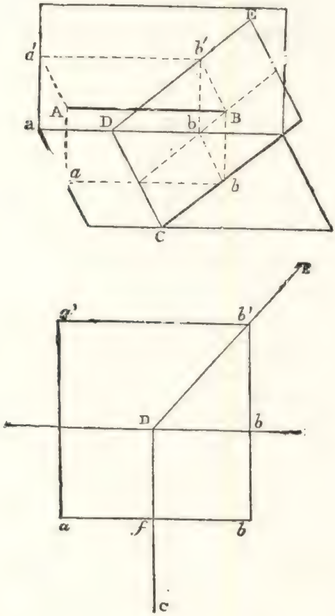

Fig. 17.

projection, the problem is more difficult; as, however, the second case is not of much practical value, it will not be considered.

3. STRAIGHT-SIDED SOLIDS.

XIII. Given the horizontal projection of a regular tetrahedron, to find its vertical projection.

Let A B C d (Fig. 18) be the given projection of the tetrahedron, which has one of its faces coincident with the ground-line. From d draw an indefinite line

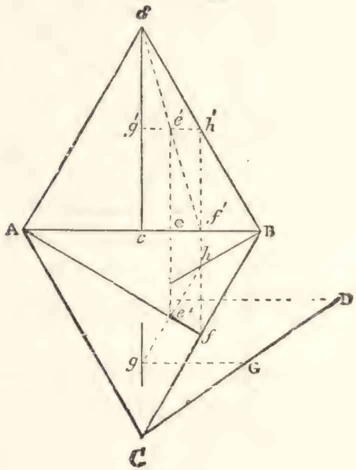

Fig. 18.

d D perpendicular to d C, and make C D equal to C B, C A. or A B; d D will be the height sought, which is carried to the vertical projection from c to d. Join A d and B d, and the vertical projection is complete. This problem might be solved in other ways.

XIV. A point being given in one of the projections of a tetrahedron, to find the point on the other projection.

Let e be the point given in the horizontal projection (Fig. 18). It may be considered as situated in the plane C B d, which is inclined to the horizontal plane, and of which the vertical projection is the triangle c B d. According to the general method, the vertical projection of the given point is to be found somewhere in a perpendicular raised on its horizontal projection e. If through d and the point e be drawn a line produced to the base of the triangle in f, the point e will be on that line, and its vertical projection will be on the vertical projection of that line f e d, at the intersection of it with the perpendicular raised on e. If through e be drawn a straight line g h, parallel to C B, this will be a horizontal line, whose extremity h will be on B d. The vertical projection of d B is d B; therefore, by raising on h a perpendicular to A B, there will be obtained h, the extremity of a horizontal line represented by h g in the horizontal plane. If through h is drawn a horizontal line h g this line will cut the vertical line raised on e in e, the point sought. If the point had been given in g on the arris c d, the projection could not be found in the first manner; but it could be found in the second manner, by drawing through g, a line parallel to C B, and prolonging the horizontal line drawn through h, to the arris c d, which it would cut in g, the point sought. The point can also be found by laying down the right-angled triangle C d D (which is the development of the triangle formed by the horizontal pro-

jection of the arris C d, the height of the solid, and the length of the arris as a hypotenuse), and by drawing through g the line g G perpendicular to C d, to intersect the hypotenuse in G, and carrying the height g G from e to g in the vertical projection. One or other of these means can be employed according to circumstances. If the point had been given in the vertical instead of the horizontal projection, the same operations inverted would require to be used.

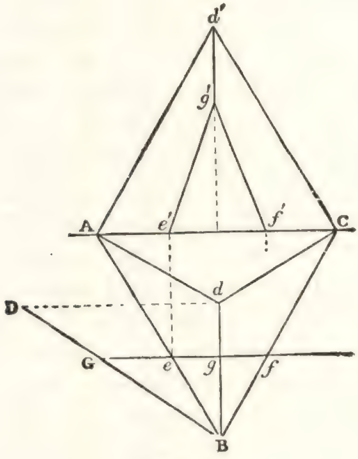

Fig. 19.

XV. Given a tetrahedron, and the trace of a plane (perpendicular to one of the planes of projection) cutting it, by which it is truncated, to find the projection of the section.

First when the intersecting plane is perpendicular to the horizontal plane (Fig. 19), the plane cuts the

base in two points e f, of which the vertical projections are e and f; and the arris B d is cut in g, the vertical projection of which can readily be found in any of the ways detailed in the last problem. Having found g join e g f g and the triangle e g f is the projection of the intersection sought.

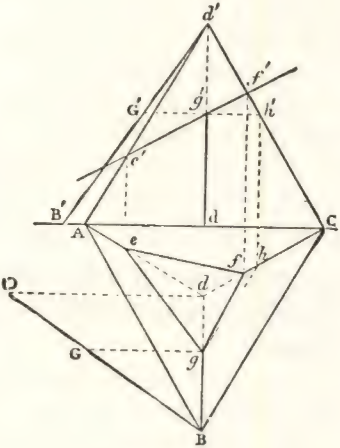

Fig. 20.

When the intersecting plane is perpendicular to the vertical plane, as e f in Fig. 20, the horizontal projections of the three points e g f have to be found. The point g in this case may be obtained in several ways. First by drawing G g h through g, then through h drawing a perpendicular to the base, produced to the arris at h, in the horizontal projection, and then drawing h g parallel to C B, cutting the arris B d in g, which is the point required. Second, on d B, the hor-

izontal projection of the arris, construct a triangle d D B, d B being the altitude of the tetrahedron, and B D the arris, and transfer this triangle to the vertical projection at d d B. From g draw the horizontal line cutting B d in G; g G is the horizontal distance of the required point in the arris, from the vertical axis of the tetrahedron as d is horizontal projection of the vertical axis, and d B the horizontal projection of the arris, it follows that the length gG, transferred to d g, will give the required point g. The points e and f are found by drawing lines from e and f perpendicular to the ground-line, and producing them till they meet the horizontal projections of the arrises in e and f. The triangle e f g is the horizontal projection of the section made by the plane e f.

XVI. The projections of a tetrahedron being given, to find its projections when inclined to the horizontal plane in any degree.

Let A B C d (Fig. 21) be the horizontal projection of a tetrahedron, with one of its sides coincident with the horizontal plane, and e d B its vertical projection; it is required to find its projections when turned round the arris A B as an axis. The base of the pyramid being a horizontal plane, its vertical projection is the right line c B. If this line is raised to c by turning on B, the horizontal projection will be A c2 B. When the point c, by the raising of B c, describes the arc c c, the point d will have moved to d, and the perpendicular let fall from that point on the horizontal plane will give d3, the horizontal projection of the extremity of the arris C d; for as the summit d moves in the same plane as C, parallel to the vertical plane

of projection the projection of the summit will evidently be in the prolongation of the arris C d, which is the horizontal projection or trace of that plane. The process therefore, is very simple and is as follows: Construct at the point B the angle required, c B c, and make the triangle c d B equal to c d B;

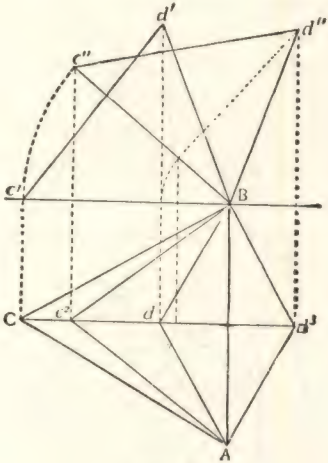

Fig. 21.

from d let fall a perpendicular cutting the prolongation of the arris C d in d3, and from c a perpendicular cutting the same line in c2; join B c2, A c2, B d3, A d3.

The following is a more general solution of the problem: Let A B C d (Fig. 22), be the horizontal projection of a pyramid resting with one of its sides on the horizontal plane, and let it be required to raise, by its angle C, the pyramid by turning around the arris A B, until its base makes with the horizontal

plane any required angle, as 50°. Conceive the right line C e turning round e, and still continuing to be perpendicular to A B, until it is raised to the required angle, as at e C. If a perpendicular be now let fall from C, it will give the point C as the horizontal projection of the angle C in its new position. Conceive

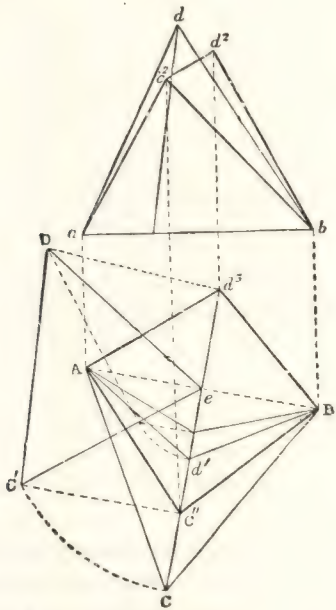

Fig. 22.

a vertical plane to pass through the line C e. This plane will necessarily contain the required angle. Suppose, now we lay this plane down in the horizontal projection thus: Draw from e the line e C, making

with e C an angle of 50°, and from e with the radius e c describe an arc cutting it in C. From C let fall on C e, a perpendicular on the point C, which will then be the horizontal projection of C in its raised position. On C e draw the profile of the tetrahedron C D e inclined to the horizontal plane. From D let fall a perpendicular on C e produced, and it will give d as the horizontal projection of the summit of the pyramid in its inclined position. Join A d, B d, A c, B c to complete the figure. The vertical projection of the tetrahedron in its original position is shown by a d b, and in its raised position by a, c2, d2, b, the points c2, and d2 being found by making the perpendiculars c3 c2 and d3 d2 equal to C C and d D respectively.

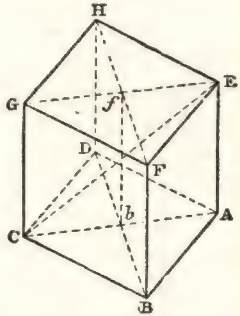

Fig. 23.

XVII. To construct vertical and horizontal projections of a cube, the axis 1 of which are perpendicular to the horizontal plane.

If an arris of the cube is given, it is easy to find its axis, as this is the hypotenuse of a right-angled triangle, the shortest side of which is the length of an

arris, and the longest the diagonal of a side. Conceive the cube cut by a vertical plane passing through its diagonals E G, A C (Fig. 23), the section will be the rectangle A E G C. Divide this into two equal right-angled triangles, by the diagonal E C. If in the upper and lower faces of the cube, we draw the diagonals F H, B D, they will cut the former diagonals in the points f and b. Now, as the lines b B, b D, f F, f H, are perpendicular to the rectangular plane A E G C, f b may be considered as the vertical projection of B F and D H, and from this consideration we may solve the problem.

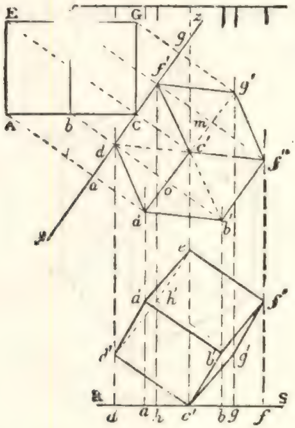

Fig. 24.

Let A E (Fig. 24) be the arris of any cube. The letters here refer to the same parts as those of the preceding diagram (Fig. 23). Through A draw an indefinite line. A C, perpendicular to A E Set off on

this line, from A to C, the diagonal of the square of A E, and join E C, which is then the axis of the cube. Draw the lines E G, G G, parallel respectively to A C and A E, and the resulting rectangle, A E G C, is the section of a cube on the line of the diagonal of one of its faces. Divide the rectangle into two equal parts by the line b f, which is the vertical projection of the lines B F, D H (Fig. 23), and we obtain, in the figure thus completed, the vertical projection of the cube, as a c b d (Fig. 25).

Through C (Fig. 24), the extremity of the diagonal E C draw y z perpendicular to it, and let this line represent the common section or ground-line of the two planes of projection. Then let us find the horizontal projection of a cube of which A E G C is the vertical projection. In the vertical projection the axis E C is perpendicular to y z, and consequently, to the horizontal plane of projection, and we have the height above this plane of each of the points which terminate the angles. Let fall from each of these points perpendiculars to the horizontal plane, the projections of the points will be found on these perpendiculars. The horizontal projection of the axis E C will be a point on its prolongation, as c. This point might have been named e with equal correctness, as it is the horizontal projection of both the extremities of the axis, C and E. Through c draw a line parallel to y z, and find on it the projections of the points A and G, by continuing the perpendiculars A a, G g, to a and g. We have now to find the projections of the points b f (representing D B F H, Fig. 23,), which will be somewhere on the perpendiculars b b, f f, let fall

from them. We have seen in Fig. 23 that B F, D H are distant from b f by an extent equal half the diagonal of the square face of the cube. Set off, therefore, on the perpendiculars b b and f f, from o and m, the distance. A b in d, b, and f, f and join d a, a b, b f, f g, g f, to complete the hexagon which is the horizontal projection of the cube. Join f e, f e, and a c, to give the arrises of the upper half of the cube. The dotted lines d c, b c, g c, show the arrises of the lower side. Knowing the heights of the points in these vertical projections, it is easy to construct a vertical projection on any line whatever, as that on R S below.

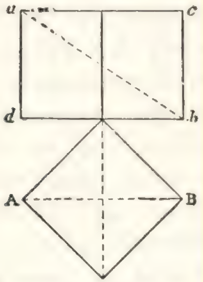

Fig. 25.

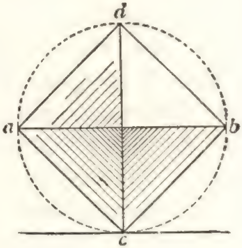

Fig. 26.

XVIII. To construct the projections of a regular octahedron, when one of its axis is perpendicular to either plane of projection.

Describe a circle (Fig. 26), and divide it into four equal parts by the diameters, and draw the lines a d, d b, b c, c a; a figure is produced which serves for either the vertical or the horizontal projection of the octahedron. when one of its axis is perpendicular to either plane

XIX. One of the faces of an octahedron being given, coincident with the horizontal plane of projection, to construct the projections of the solid.

Let the triangle A B C (Fig. 27) be the given face. If A be considered to be the summit of one of the two pyramids which compose the solid, B C will be one of the sides of the square base, k C B i. The base makes with the horizontal plane an angle, which is easily found. Let fall from A a a perpendicular on B c, cutting it in d, with the length B c as a radius, and from

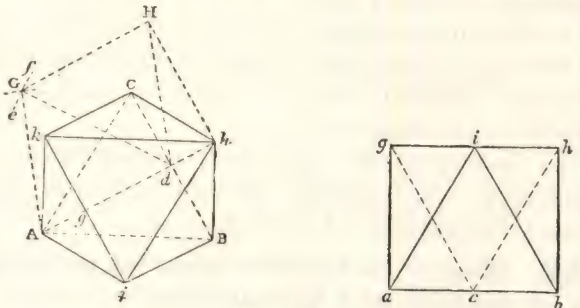

Fig. 27.

d as a centre, describe the indefinite arc e f. The perpendicular A d will be the height of each of the faces, and, consequently, of that which, turning on A, should meet the side of the base which has already turned on d. Make this height turn on A, describing from that point as a centre, with the radius A d, an indefinite arc, cutting the first arc in G, the point of meeting of one of the faces with the square base; draw the line G A, G d: the first is the profile or inclination of one of the faces on the given face A B C according to the angle d A G; the second, d G, is the inclination of the square base,

which separates the two pyramids in the angle A d G. The face adjacent to the side B C is found in the same manner. Through G, draw the horizontal line G H equal to the perpendicular A d. This line will be the profile of the superior face. Draw d H, which is the profile of the face adjacent to B C. From H let fall a perpendicular on A d produced, which gives the point h for the horizontal projection of H, or the summit of the superior triangle parallel to the first, draw h i parallel to C A, h k parallel to A B, A k and B h perpendicular to A B, and join k C, C h, B i, and A i and the horizontal projection is complete. From the heights we have thus obtained we can now draw the vertical projection shown in No. II, in which the parts have the same letters of reference.

The finding of the horizontal projection may be abridged by constructing a hexagon and inscribing in it the two triangles A C B, h i k.

XX. Given in the horizontal plane the projection of one of the faces of a dodecahedron, to construct its projections.

The dodecahedron is a twelve-sided solid, all the sides being regular and equal pentagons. It is necessary, in order to construct the projection, to discover the inclination of the faces among themselves. Let the pentagon A B C D E (Fig. 28) be the side on which the body is supposed to be seated on the plane. Conceive two other faces, E F G H D and D I K L C, also in the horizontal plane, and then raised by being turned on their bases, E D, D C. By their movement they will describe in space arcs of circles, which will terminate by the meeting of the sides D H, D I.

To find the inclination of these two faces.—From the points I and II let fall perpendiculars on their bases produced. If each of these pentagons were raised vertically on its base, the horizontal projection of H and I would be respectively in z z· but as both are raised

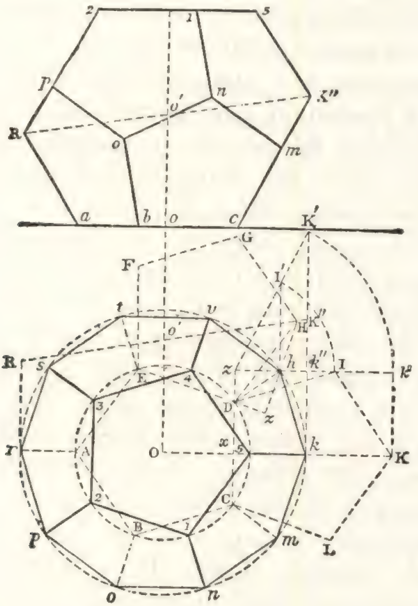

Fig. 28.

together, the angles H and I would meet in space above h where the perpendiculars intersect therefore, h will be the horizontal projection of the point of meeting of the angles. To find the horizontal projection of K, prolong indefinitely z I, and set off from z on z I the length z K in k; from z as centre with radius z I, describe

the arc II cutting the perpendicular h I in I; join z I; then from z as centre, with the radius z k, describe an arc cutting z I produced in the point K, from which let fall on z k a perpendicular K k, and produce it to k in x K. If, now, the right-angled triangle z k K, were raised on its base, k would be the projection of K. Conceive now the pentagon C D I K L turned round on C D, until it makes an angle equal to k z K with the horizontal plane, the summit K will then be raised above k by the height k K, and will have for its horizontal projection the point k. In completing the figure practically;—from the centre o, describe two concentric circles passing through points h D. Draw the lines h D, h k, and carry the last round the circumference in m n o p r s t u: through each of these lines draw radially the lines m C, o B, r A, t E, and these lines will be the arrises analogous to h D. This being done, the inferior half of the solid is projected. By reason of the regularity of the figure, it is easy to see that the six other faces will be similar in those already drawn, only that although the superior pentagon will have its angles on the same circumference as the inferior pentagon the angles of the one will be in the middle of the faces of the other. Therefore, to describe the superior half;—through the angles n p s v k, draw the radial lines n 1, p 2, s 3, v 4, k 5, and join them by the straight lines 1 2, 2 3, 3 4, 4 5, and 5 1.

To obtain the length of the axis of the solid, observe that the point k is elevated above the horizontal plane by the height k K: carry that height to k K: the point r, analogous to h, is raised the same height as that point, that is to say h i, which is to be carried from r

to R; and the line R K is the length sought. As this axis should pass through the centre of the body, if a vertical projection of the axis in O, and therefore O o is the half of the height of the solid vertically. By doubting this height, and drawing a horizontal line to cut the vertical lines of the angles of the superior face is obtained, as in the upper portion of (Fig. 28), in which the same letters refer to the same parts.

XXI. One of the faces of a dodecahedron being given, to construct the projections of the solid, so that its axis may be perpendicular to the horizontal plane.

Let A B E D C (Fig. 29, 1) be the given face. The solid angles of the dodecahedron are each formed by the meeting of three pentagonal planes. If there be conceived a plane B C passing through the extremities of the arrises of the solid angle A, the result of the section would be a triangular pyramid, the sides of whose base would be equal to one of the diagonals of the face, such as B C. An equilateral triangle b c f (Fig. 29, 11) will represent the base of that pyramid inverted, that is, with its summit resting on the horizontal projection, it it required to find the height of that pyramid, or which is the same thing, that one of the three points of its base b c f, for as they are all equally elevated, the height of one of them gives the others. There is necessarily a proportion between the triangle A b c (No. 11) and A B C (No. 1), since the first is the horizontal projection of the second. A g is the horizontal projection of A G; but A G is a part of A H, and the projection of that line is required for one of the faces of the solid; therefore as A G:A g::A H:x. In other words, the length, the length of x may be ob-

tained by drawing a fourth proportion of the three lines it will be found to be equal to A h; or it may be obtained graphically thus:—Raise on A g at g an indefinite perpendicular, take the length A G (No. 1) and carry it from A to G (No. 11); g is a point in the

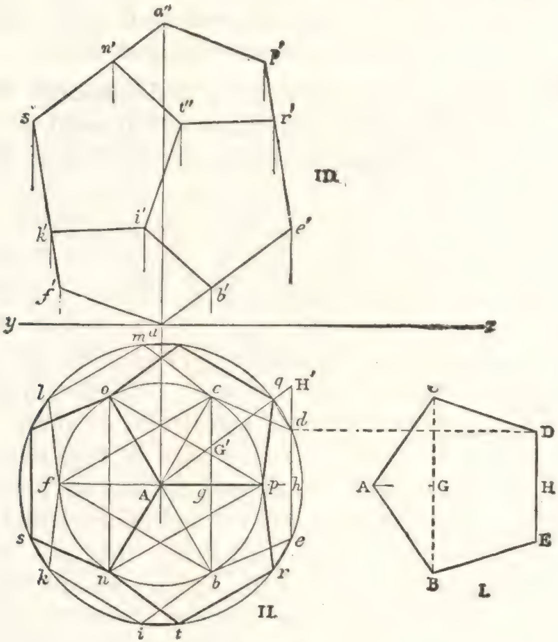

Fig. 29.

assumed pyramidal base b c f. Since A G is a portion of A H, A G will be so also. Produce A G, therefore, to H, making A H equal to A H (No. 1) and from H let fall a perpendicular on A g produced, which gives h the point sought. Produce H h, and carry on it the

length H D or H E from h to d and h to e; draw the lines c d, b e, and the horizontal projection of one of the faces is obtained inclined to the horizontal plane, in the angle H A h. As the other two inferior faces are similar to the one found, the three faces should be found on the circumference of a circle traced from A as centre, and with A d or A e as a radius. Join f A, prolong A n, A o, perpendicular to the sides of the triangle f c b, and make them equal to A h, and through their extremities draw perpendiculars, cutting the circumference in the points i k, l m. Draw the lines i b, k f, l f, m c, and the horizontal projections of the three inferior faces obtained. The superior pyramid is similar and equal to the inferior, and solely opposed by its angles. Describe a circle passing through the three points of the first triangle, and draw within it a second equilateral triangle n o p, of which the summits correspond to the middle of the faces of the former one. Each of these points will be the summit of a pentagon, as the points b c f. These pentagons have all their sides common, and it is only necessary therefore to determine one of these superior pentagons to have all the others. Six of the faces of the dodecahedron have now been projected; the remaining six are obtained by joining the angular points already found, as q d, e r, t i, k s, &c.

To obtain the vertical projection (No. 111) begin with the three inferior faces. The point A in the horizontal projection being the summit of the inferior solid angle, will have its vertical in a; the points b c f, when raised to the height g G, will be in b c f, or simply b f. The points b g c being in a plane perpendicular to

the vertical plane, will necessarily have the same vertical projection, b. The line a f will be the projection of the arris A f, and a b will be that of the arrises A b, A c, and of the line A g, or rather that of the triangle A b c, which is in a plane perpendicular to the vertical plane. But this triangle is only a portion of the given pentagonal face (No. 1), of which A H is the perpendicular let fall from A on the side E D. Produce a b to e, making a e equal to A H; e is the vertical projection of the arris e d. This arris is common to the inferior pentagon, and to the superior pentagon e d q p r, which is also perpendicular to the vertical plane, and, consequently, its vertical projection will be e p, equal to a e.

This projection can now be obtained by raising a vertical line through p, the summit of the superior pentagon, and from e as a centre, and with the radius A H or A II, describing an arc cutting this line in p, the point sought. But p n o belong to the base of the superior pyramid; therefore, if a perpendicular is drawn from n through y z to n, and the height p is transferred to n by drawing through p′ a line parallel to y z, n will be the projection of the points n and o. Through n draw s n a parallel to a e cutting perpendiculars drawn through s and A in the horizontal projection. Through s draw s f parallel to p e, and join a f, a p; set off on the perpendicular from r the height of s above y z at r, and draw r t parallel to y z, cutting the perpendicular from t, and joint n t. Draw perpendiculars from k and i through y z, to k and i, make k and i the same height as e, and draw k i, and join i b, i t. The vertical projection is now complete.

XXII. In a given sphere to inscribe a tetrahedron, a hexahedron or cube, an octahedron and a dodecahedron.

Let A B (Fig. 30) be the diameter of the given sphere. Divide it into three equal parts, D B being one of these parts. Draw D E perpendicular to A B, and draw the chords A E, E B. A E is the arris of the tetra-

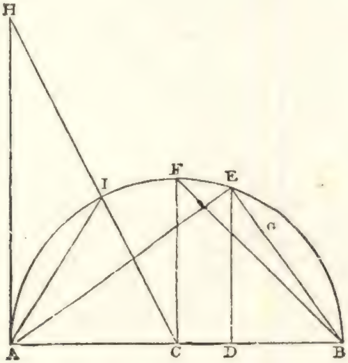

Fig. 30.

hedron, and E B the arris of the hexahedron or cube. From the centre C draw the perpendicular radius C F, and the chord F B is the arris of the octahedron. Divide B E in extreme and mean proportion in G, and B G is the arris of the dodecahedron. The arrises being known, the solids can be drawn by the help of the problems already solved. Draw the tangent A H equal to A B; join H C and A I; A I is the arris of an icosahe-

dron which can be inscribed in the sphere, an icosahedron being a solid with twenty equal sides, all of which are equilateral triangles. See Fig. 30½.

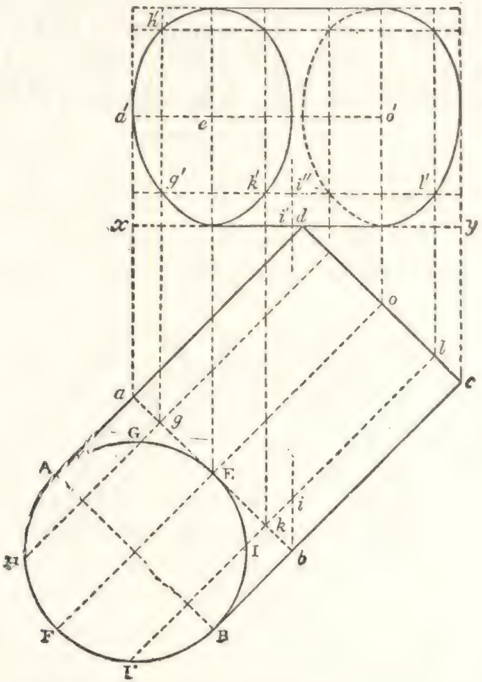

Fig. 30½.

4. THE CYLINDER, CONE, AND SPHERE.

XXIII. The horizontal projection of the cylinder, the axis of which is perpendicular to the horizontal plane, being given to find the vertical projection.

Let the circle A B C D (Fig. 31) be the base of the cylinder, and also its horizontal projection. From the points A and C raise perpendiculars to the ground-line

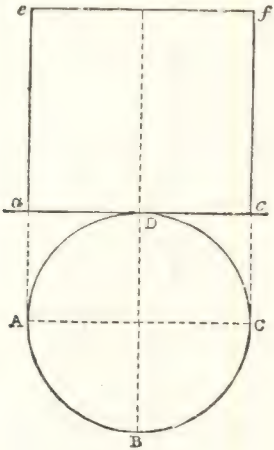

Fig. 31.

a c, and produce them to the height of the cylinder—say, for example, a e, c f. Draw e f parallel to a c, and the rectangle a e f c is the vertical projection required.

XXIV. Given the traces of an oblique plane, to determine the inclination of the plane to both the H. P. and the V. P.

Let v t and h t (Fig. 32) be the traces of the given plane. Draw the projections of a semi-cone having its axis a′ b′ in the vertical plane, the apex a′ in the given v t and its base (a semi-circle) c e d in the h p and lying tangentially to the given h t. Then the base angle (0) of the cone gives the inclination of the plane to the h p. To determine the inclination of the plane to the v. p., draw the projections of a second semi-cone, having the axis m n in the h p, and the apex m in the

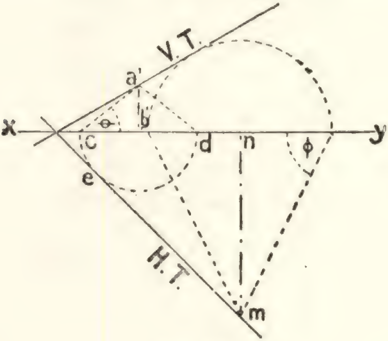

Fig. 32.

given h t, while the base is in the v p and tangential to the v t. The base angle (0) of this cone gives the inclination to the v p.

XXV. The base of a cylinder being given, and also the angles which the base makes with the planes of projection, to construct the projections of the cylinder.

Let the circle AGBH (Fig. 33) be the given base, and let each of the given angles be 45°. Draw the diameter AB, making an angle of 45° with the ground line or ver-

tical plane, and draw the line A B, making with A B the given angle; and from A as a centre, with A B and A C as radii, describe arcs cutting A B in B and C. Then draw A D, B E perpendicular to A B and equal

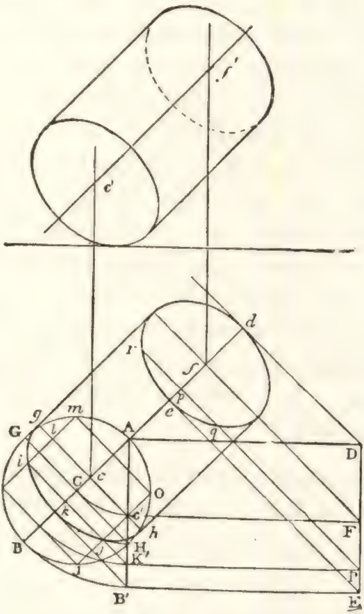

Fig. 33.

to the length of the cylinder; the rectangle A E is the vertical projection of the cylinder parallel to the vertical plane and inclined to the horizontal plane A B in an angle of 45°. Now prolong indefinitely the diameter B A, and this line will represent the projection on the horizontal plane of the line in which the generating circle moves to produce the cylinder.

If from B and C perpendiculars be let fall on A B, k will be the horizontal projection of B, A k that of the diameter A B, and c that of the centre C. Through c draw h g perpendicular to A B, and make c h, c g equal to C H, G G; and the two diameters of the ellipse, which is the projection of the base of the cylinder, will be obtained; namely, A k and h g.

In like manner, draw D F E the lines D d, F f, E e, perpendicular to the diameter A B produced, and their intersections with the diameter and the sides of the cylinder will give the means of drawing the ellipse which forms the projection of the farther end of the cylinder. The ellipses may also be found by taking any number of points in the generating circle as I J, and obtaining their projections i j. The method of doing this, and also of drawing the vertical projection e f, will be understood without further explanation.

XXVI. A point in one of the projections of a cone being given, to find it in the other projection.

Let a (Fig. 34) be the given point. This point belongs equally to the circle which is a section of the cone by a plane passing through the point parallel to the base, and to a straight line forming one of the sides of a triangle which is the section of the cone by a plane perpendicular to its base and passing through its vertex and through the given point, and of which f a g is the horizontal, and f a g the vertical projection. To find the vertical projection of a, through a draw a a perpendicular to b c, and its intersection with f g is the point required; and reciprocally, a in the

horizontal projection may be found from a in the vertical projection, in the same manner.

Otherwise, through a, in the horizontal projection, describe the circle a d c, and draw e e or c c, cutting

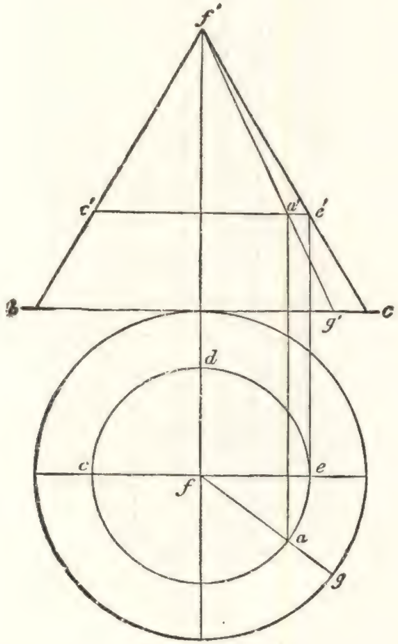

Fig 34.

the sides of the cone in e and c; draw c e parallel to the base, and draw a a, cutting it in a, the point required.

XXVII. On a given cylinder to describe a helix.

Let a b c d, &c. (Fig. 35), be the horizontal projection of the given cylinder. Take on this curve a series of equal distances, a b, b c c d, &c., and through each

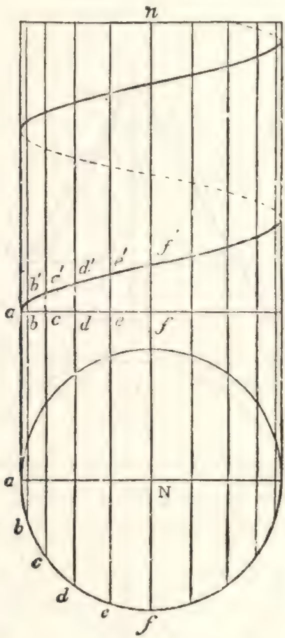

Fig. 35

of the points a, b, c, &c. draw a vertical line, and produce it along the vertical projection of the cylinder. Then conceive a curve cutting all these verticals in the points a b c d, in such a manner that the height of the point above the ground-line may be in constant relation to the arcs a b, b c, c d; for example, that a may

ne the zero of height, that bb may be 1, c c 2, d d 3, &c.; then this curve is named a helix. To construct this curve, carry on the vertical projection on each vertical line such a height as has been determined, as 1 on b, 2 on c, 3 on d; and through these points will pass the curve sought. It is easy to see that the curve

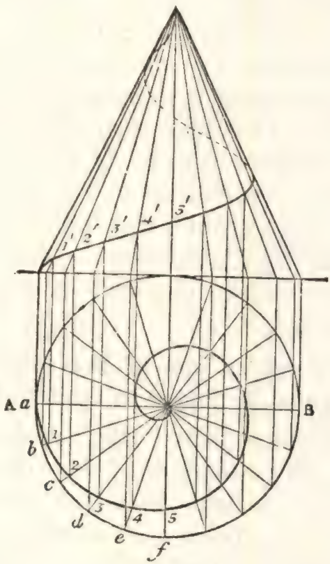

Fig. 36.

so traced is independent of the cylinder on which it has been supposed to be traced; and that if it be isolated, its horizontal projection will be a circle. The helix is named after the curve which is its horizontal projection. Thus the helix in the example is a helix with a circular base. The vertical line f n is the axis

of the helix, and the height b b, comprised between two consecutive intersections of the curve with a vertical, is the pitch of the helix.

XXVIII. On a given cone to describe a helix.

Let the projections of the given cone be as shown in Fig. 36. Divide the base of the cone in the horizontal projection into any number of equal parts, as a b, b c, c d, &c., and draw lines from the vertex to the points thus obtained. Set off along these lines a series of distances increasing in constant ratio, as 1 at b, 2 at c, 3 at d, &c. The curve then drawn through these points when supposed to be in the same plane, is called a spiral. If these points, in addition to approaching the centre in a constant ratio, are supposed also to rise above each other by a constant increase of height, a helical curve will be obtained on the vertical projection of the cone.*

XXIX. A point in one of the projections of the sphere being given, to find it in the other projection.

Let a be the given point in the horizontal projection of the sphere h b c i (Fig. 38). Any point on the surface of a sphere belongs to a circle of that sphere. Therefore, if a is a point, and a vertical plane b c is made to pass through that point to A B, the section of

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*The octahedron is formed by the union of eight equilateral triangles; or, more correctly, by the union of two pyramids with square bases, opposed base to base, and of which all the solid angles touch a sphere in which they may be inscribed.

It is essential that the diagram should be clearly *seen* as a solid, and not as a mere set of lines in one plane. Imagine *h* as the apex of one pyramid on the base *k* C B *i*, and A as the apex of the other pyramid on the opposite side of the same base. The octahedron is shown to be lying on its side A B C.

the sphere by this plane will be a circle, whose diameter will be b c, and the radius consequently, d b or d c; and the point a will necessarily be in the circumference of this circle. Since the centre d of this circle is situated on the horizontal axis of the sphere, and

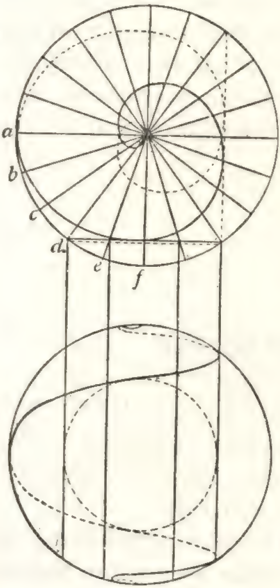

Fig. 37.

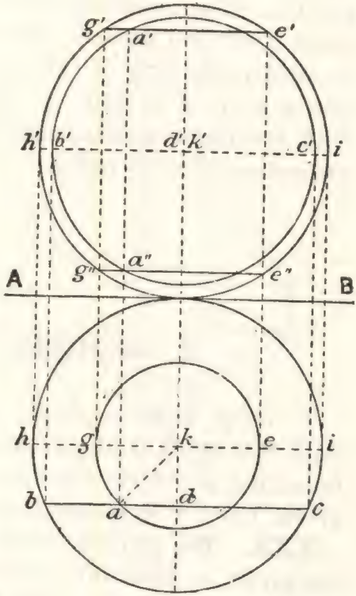

Fig. 38.

as this axis is perpendicular to the vertical plane, its vertical projection will be the point d. It is evident that the vertical projection of the given point a will be found in the circumference of the circle described from d with the radius d b or d c and at that point of it where it is intersected by the line drawn through

a, perpendicular to A B. Its vertical projection will therefore be either a or a, according as the point a is on the superior or inferior semi-surface of the sphere.

The projection of the point may also be found thus: Conceive the sphere cut by a plane parallel to the horizontal plane of projection passing through the given point a. The resulting section will be the horizontal circle described from k, with the radius k a; and the vertical projection of this section will be the straight line g e, or g e; and the intersections of these lines with the perpendicular drawn through a, will be the projection of a, as before.

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5. SECTIONS OF SOLIDS.

To draw sections of any solid requires little more than the application of the method described in the foregoing problems. Innumerable examples might be given, but a few selected ones will suffice.

XXX. The projections of a regular tetrahedron being given, to draw the section made by a plane perpendicular to the vertical plane and inclined to the horizontal plane.

Let A B C D and a b c d (Fig. 39) be the given projections, and E F G the given plane perpendicular to the vertical plane and inclined to the horizontal plane at an angle of 30°. The horizontal projection e f g of the section is easily found as shown. To find the correct section draw through e, f, and g, lines parallel to

the ground-line A C, and a c one of them as E e set off the distances E F, E G at E f and E g, and through f and g draw perpendiculars cutting the other lines in F and G′. Join E G, G F, and F E. E F G is the correct section made by the plane.

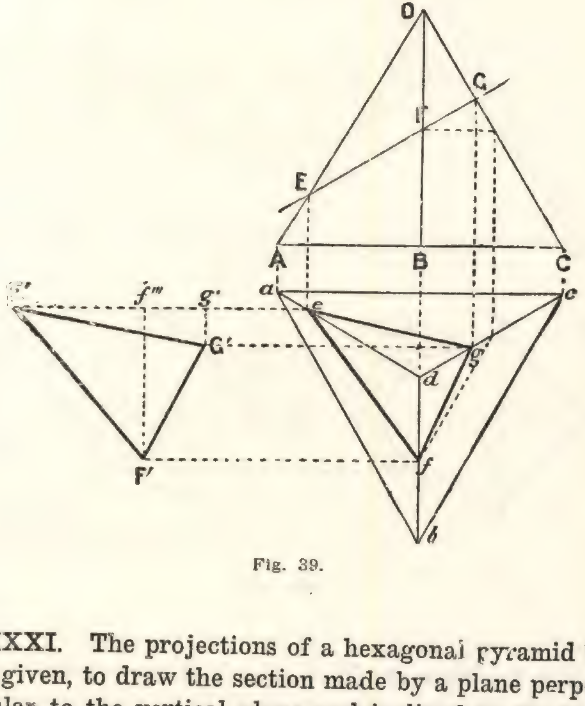


Fig. 39.

XXXI. The projections of a hexagonal pyramid being given, to draw the section made by a plane perpendicular to the vertical plane and inclined to the horizontal plane.

Let A B C D and a b c d e f g (Fig. 40) be the given projections, and H I J K the given plane. T horı-

zontal projection h i j k l m of the section is easily found as shown. Through m, l, h, j, and i draw lines parallel to the ground-line A D, and on one of them as h m, set off the distances H I, H J, H K, at h M,

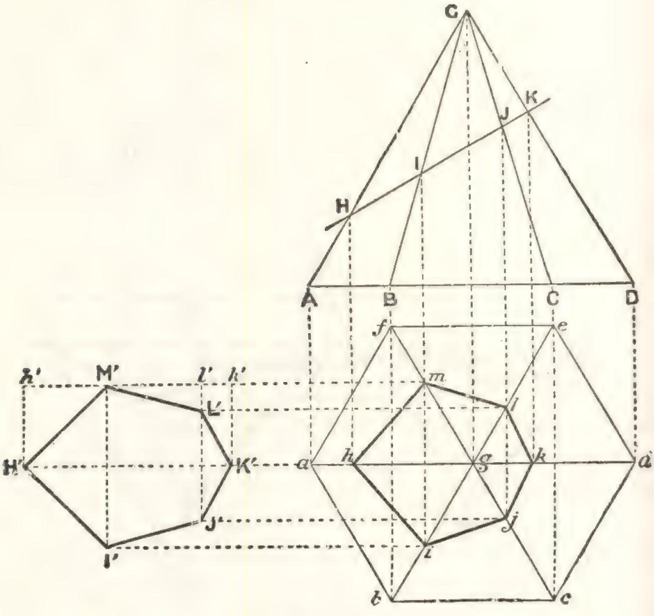


Fig 40.

h l, h k. From h, M, l, and k draw perpendiculars meeting the other lines in H, I, L, J, and K, and join the points of intersection. H I J K L M is the true section made by the plane.

XXXII. **The projections of an octagonal pyramid being given, to draw the section made by a vertical plane.**

Let A B C D F and a b c d e f (Fig. 41) be the given projections, and g h i j k of the section made by the plane is easily found by drawing g g, h h, i i, &c., perpendicular to the ground-line A D. On A D produced set off the distances g h, h i, i j, and j k at G h, h i, &c., and from the points thus found draw perpendiculars to G K meeting lines drawn from h, i, and j parallel to A D, in H, I, and J. Join G H, H I, I J, and J K. G H I J K is the true section made by the plane.

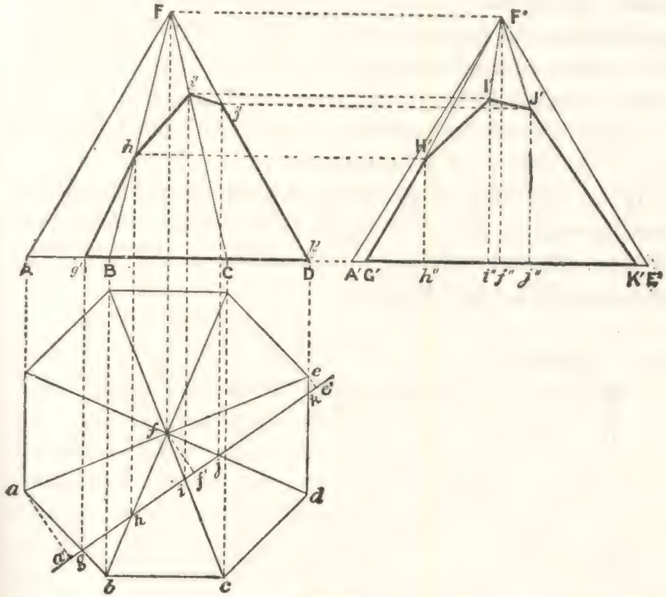


Fig. 41.

A cylinder may be cut by a plane in three different ways—1st, the plane may be parallel to the axis; 2nd, it may be parallel to the base; 3rd, it may be oblique to the axis or the base.

In the first case the section is a parallelogram, whose length will be equal to the length of the cylinder, and whose width will be equal to the chord of the circle of the base in the line of section. Whence it follows, that the largest section of this kind will be that made by a plane passing through the axis; and the smallest will be when the section plane is a tangent—the section in that case will be a straight line.

When the section plane is parallel to the base, the section will be a circle equal to the base. When the section plane is oblique to the axis or the base, the section will be an ellipse.

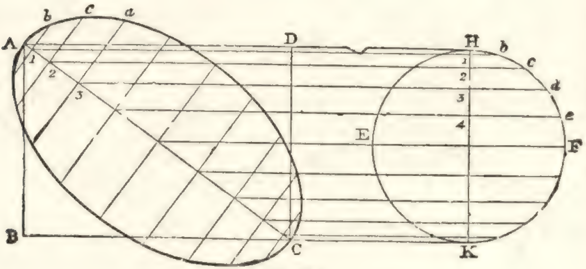


Fig. 42.

XXXIII. To draw the section of a cylinder by a plane oblique to the axis.

Let A B C D (Fig. 42) be the projection of a cylinder, of which the circle E H F K represents the base divided into twenty equal parts at b c d e, &c., and let it be required to draw the section made by the plane

A C. The circular base must be drawn in such a position that the axis of the cylinder when produced meets the centre of the circle. Through the centre of the circle draw the diameter H K perpendicular to the axis produced. Then through the divisions of the base, b c d, &c., draw lines parallel to the axis, and meeting the section plane in 1, 2, 3, &c., and through these points draw perpendiculars to A C making them equal to the corresponding perpendiculars from H K, i e, 1 b, 2 c, 3 d, &c. A curve drawn through the points thus found will be an ellipse, the true section of A B C D on the plane A C.*

The Cone. A cone may be cut by a plane in five different ways, producing what are called the conic sections: 1st. If it is cut by a plane passing through the axis, the section is a triangle, having the axis of a cone as its height, the diameter of the base for its base, and the sides for its sides. If the plane passes through the vertex, without passing through the axis, as c e (Fig. 43), the section will still be a triangle, having for its base the chord c e, for its altitude the line c e, and for its sides the sides of the cone, of which the lines c e, o e are the horizontal and the line c e the vertical projections. 2nd. If the cone is cut parallel to base, as in g h, the section will be a circle, of which g h will be the diameter. 3rd. When the section plane is oblique to the axis, and passes through the opposite sides of the cone, as m p h, the section will be an ellipse, m n h. 4th. When the plane is parallel to one of the sides of the cone, as r h. the resulting sec-

*The point is assumed to be in the inferior half of the cylinder.

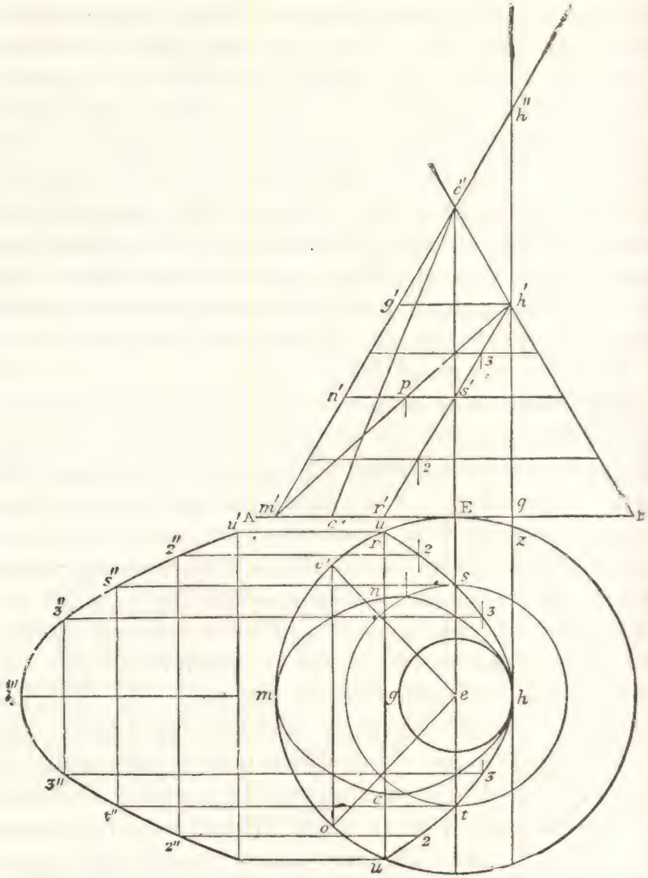


Fig. 43.

tion is a parabola r s h t u. 5th. When the section plane is such as to pass through the sides of another cone formed by producing the sides of the first be-

yond the vertex, as the plane q h, the resulting curve in each cone in a hyperbola.

Several methods of drawing the curves of the conic sections have already been given in Plane Geometry, Vol. 1. Here their projections, as resulting from the sections of the solid by planes, are to be considered. If the mode of finding the projections of a point on the surface of a given cone be understood, the projections of the curves of the conic sections will offer no difficulty. Let the problem be: First, to find the projections of the section made by the plane m h. Take at pleasure upon the plane the several points, as p, &c. Let fall from these points perpendiculars to the horizontal plane, and on these will be found the horizontal projection of the points; thus, in regard to the point p ——. Draw through p a line parallel to A B: this line will be the vertical projection of the horizontal plane cutting the cone, and its horizontal projection will be a circle, with s n for its radius. With this radius, therefore, from the centre e, describe a circle cutting, twice, the perpendicular let fall from p; the points of intersection will be two points in the horizontal projection of the circumference of the ellipse. In the same manner, any other points may be obtained in its circumference. The operation may often be abridged by taking the point p in the middle of the line m h; for then m h will be the horizontal projection of the major axis, and the two points found on the perpendicular let fall from the central point p will give the minor axis.

To obtain the projections of the parabola, more points are required, such as r, 2, s, 3, h, but the mode

of procedure is the same as for the ellipse. The vertical projection of the parabola u s h t u is shown at u s h t u.

The projections of the section plane which produces the hyperbola are in this case straight lines, q h, z h.

XXXIV. To draw the section of a cone made by a plane cutting both its sides, i. e., an ellipse.

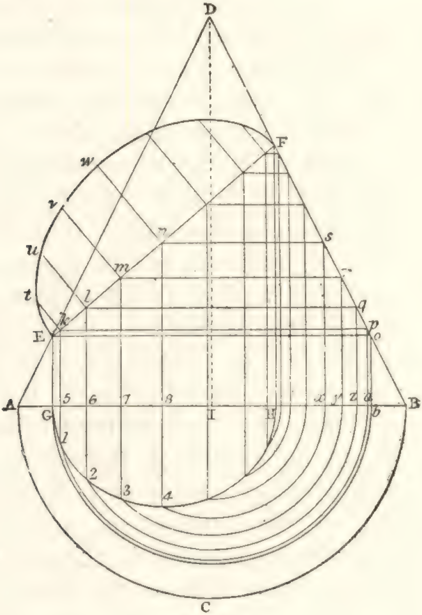


Fig. 44.

Let A D B (Fig. 44) be the vertical projection of the cone A C B the horizontal projection of half its base, and E F the line of section. From the points E and F let fall on A B the perpendiculars E G. F H.

Take any points in E F, as k, l, m, n, &c., and from them draw lines parallel to A B, as k p, l q, m r, &c., and also lines perpendicular to A B, as k l, 12 m 3, &c. Also from p, q, r, &c., let fall perpendiculars on A B, namely, p a, q z, r y, &c. From the centre of the base of the cone, l, with radius la, lz, ly, &c., describe arcs cutting the perpendiculars let fall from k, l, m, &c., in 1, 2, 3, &c. A curve traced through these points will be the horizontal projection of the section made by the plane E F. To find the true section,—Through k, l, m, &c., draw kt, lu, m v, n w, perpendicular through E F, and make them respectively equal to the corresponding ordinates, 5 1, 6 2, 7 3, &c., of the horizontal projection G 4 H, and points will be obtained through which the half E w F of the required ellipse can be traced. It is obvious that, practically it is necessary only to find the minor axis of the ellipse, the major axis E F being given.

XXXV. To draw the section of a cone made by a plane parallel to one of its sides, i. e., a parabola

Let A D B (Fig. 45) be the vertical projection of a right cone, and A C B half the plan of its base; and let E F be the line of section. In E F take any number of points, E, a, b, c, e, F, and through them draw lines E H, a 61, b 7 2, &c., perpendicular to A B, and also lines parallel to A B, meeting the side of the cone in f, g, h, k, 1: from these let fall perpendiculars on A B, meeting it in m n, o, p, q. From the centre of the base l, with the radii lm, ln, lo, &c., describe arcs cutting the perpendiculars let fall from the section line in the points 1, 2, 3, 4, 5; and through the points of intersection trace the line H 12345G, which is the horizontal

projection of the section. To find the true section, from E, a, b, c, d, e, raise perpendiculars to E F, and make them respectively equal to the ordinates in the horizontal projection, as E r equal to E H, a s equal to

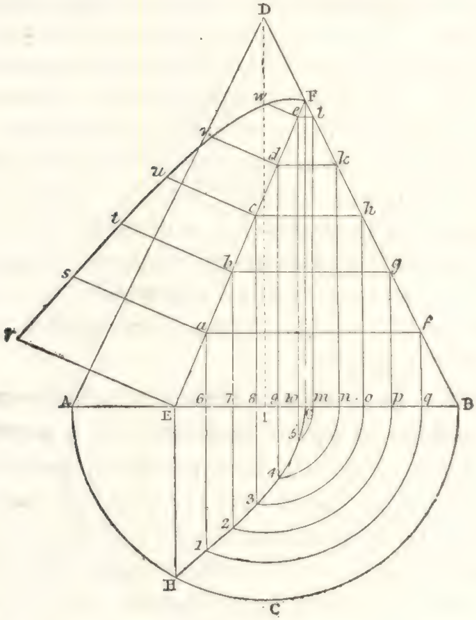


Fig. 45.

5 1, &c., and the points r s t u v w in the curve will be obtained. The other half of the parabola can be drawn by producing the ordinates w e, v d, &c., and setting the same distances to the right of E F.

XXXVI. To draw the section of a cone made by a plane parallel to the axis, i. e., an hyperbola.

Let d c d (Fig. 46) be the vertical projection of the cone, d q r d one half of the horizontal projection of the base, and q r the section plane. Divide the line r q into any number of equal parts in 1, 2, 3, h, &c., and

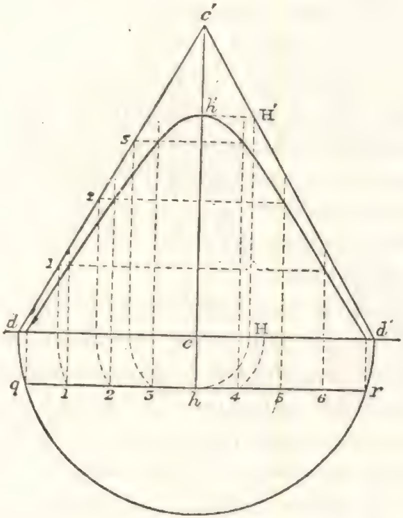


Fig. 46.

through them draw lines perpendicular to d d. From c as centre, with the radii c1, c2, &c., describe the arcs cutting d d; and from the points of intersection draw perpendiculars cutting the sides of the cone in 1, 2, 3, and these heights transferred to the corresponding perpendiculars drawn directly from the points 1, 2, 3, &c., in r q, will give points in the curve.

XXXVII. To draw the section of a cuneoid made by a plane cutting both its sides.

Let A C B (No. 1, Fig. 47) be the vertical projection of the cuneoid, and A 5 B the plan of its base, and A B (No. 4) the length of the arris at C, and let D E be the line of section. Divide the semi-circle of the base into any number of parts, 1, 2, 3, 4, 5, &c., and through them draw perpendiculars to A B, cutting it in l, m, n, o, p, &c., and join Cl, C m, Cn, &c., by lines cutting the section line in 6, 7, 8, 9 &c. From these points draw lines perpendicular to D E and make them equal to the corresponding ordinates of the semi-circle, either by transferring the lengths by the compasses, or by proceeding as shown in the figure. The curve drawn through the points thus obtained will give the required section.

The section on the line D K is shown in No. 2, in which A B equals D K; and the divisions e f g h k in D K, &c., are transferred to the corresponding points on A B; and the ordinates e l, f m, g n, &c., are made equal to the corresponding ordinates l1, m2, n3, of the semi-circle of the base. In like manner, the section of the line G H, shown in No. 3, is drawn.*

XXXVIII. To describe the section of a cylinder made by a curve cutting the cylinder.

Let A B D E (Fig. 48) be the projection of the cylinder, and C D the line of the section required. On A B

*A cuneoid is a solid ending in a straight line, in which, if any point be taken, a perpendicular from that point may be made to coincide with the surface. The base of the cuneoid may be of any form; but in architecture it is usually semi-circular or semi-elliptical, and parallel to the straight line forming the other end.

describe a semi-circle, and divide it into any number of parts. From the points of division draw ordinates 1 h, 2k, 3l, 4m, &c., and produce them to meet the line of section in o, p, q, r, s, t, u, v, w. Bend a rule or slip of paper to the line C D, and prick off on its points C.

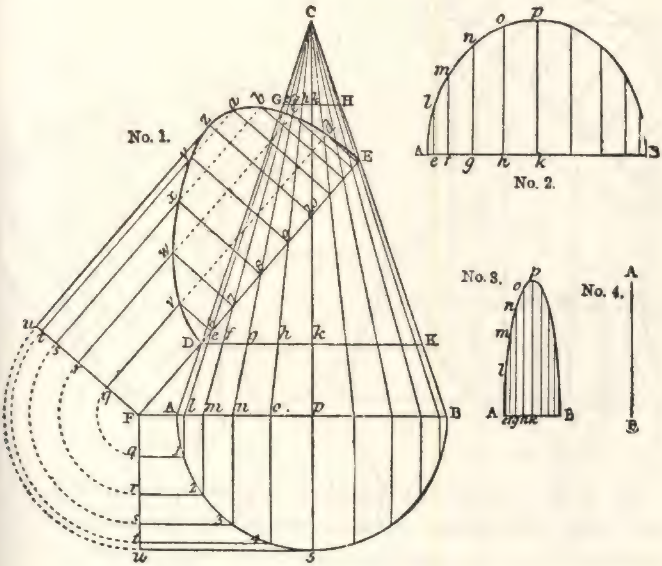


Fig. 47.

o, p, q, &c.; then draw any straight line F G, and, unbending the rule, transfer the points C, o, p, q, &c., to F, a, b, c, d, &c. Draw the ordinates a1, b 2, c 3, &c., and make them respectively equal to the ordinates h 1, k2, 13, &c., and through the points found trace the curve.

XXXIX. To describe the section of a sphere.

Let A B D C (Fig. 49) be the great circle of a sphere, and F G the line of the section required. Then since all the sections of a globe or sphere are circles, on F G describe a semi-circle F 4G, which will be the section required.

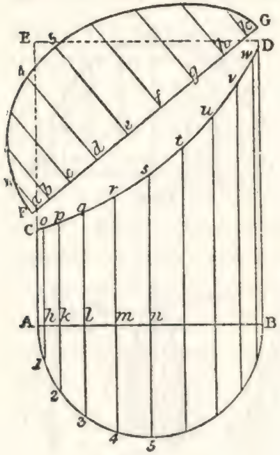


Fig. 48.

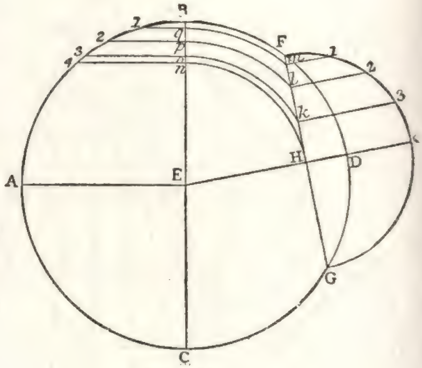


Fig. 49.

Or, in F G take any number of points, as m, l, k, H, and from the centre of the great circle E, describe the arcs H n, k o, l p, m q, and draw the ordinates II 4, k 3, 1 2, ml, and n4, o3, p2, q 1; then make the ordinates on F G equal to those on B C, and the points so obtained will give the section required.*

*The projections of sections of spheres are, if the section panes are oblique, either straight lines or ellipses, and are found as follows:

Let *a b* (Fig. 50) be the horizontal projection of the section plane. On the line of section take any number of points, as *a*, *c*, *b*, and through each of them draw a line perpendicular to *y x*.

XL. To describe the section of an ellipsoid when a section through the fixed axis, and the position of the line of the required section are given.

Let A B C D (Fig. 51) be the section through the fixed axis of the ellipsoid, and F G the position of the line of the required section. Through the centre of

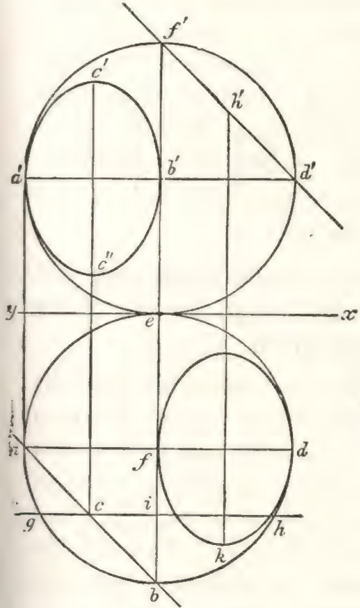


Fig. 50.

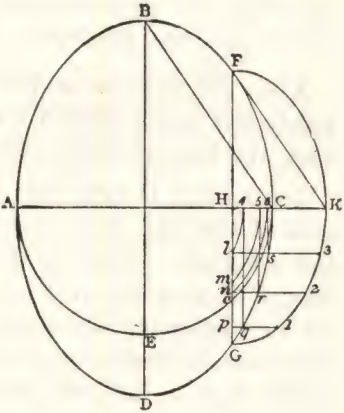


Fig. 51.

the ellipsoid draw B D parallel to F G; bisect F G in H and draw A C perpendicular to F G; join B C, and from F draw F K, parallel to B C, and cutting A C produced in K; and then will H K be the height of the semi-ellipse forming the section on F G.

Or, the section may be found by the method of ordinates, thus: As the section of the ellipsoid on the line A C is a circle, from the point of intersection of B D and A C describe a semicircle A E C. Then on H G, the line of section, take any number of points, l, m, p, and from them raise perpendiculars cutting the ellipse in q, r, s. From q, r, s draw lines perpendicular to A C, cutting it in the points 4, 5, 6; and again, from the intersection of B D and A C as centre draw the arcs 4 l, 5 m, 6n, C o, cutting H G in l, m, n, o; then H o, set off on the perpendicular from H to K, is the height of the section; and the heights H n, M m, Hl, set off on the perpendiculars from l to 3, n to 2 and p to 1, give the heights of the ordinates.

XLI. To find the section of a cylindrical ring perpendicular to the plane passing through the axis of the ring, the line of section being given.

Let A B E D (Fig. 52) be the section through the axis of the ring, A B a straight line passing through the concentric circles to the centre C, and D E be the line of section. On A B describe a semicircle; take in its circumference any points, as 1, 2, 3, 4, 5, &c., and draw the ordinates 1 f, 2 g, 3 h, 4 k, &c. Through the points f, g, h, k, l, &c., where the ordinates meet the line A B, and from the centre C, draw concentric circles, cutting the section line in m, n, o, p, q, &c. Through these points draw the lines m 1, n 2, o 3, &c., perpendicular to the section line, and transfer to them the heights of the ordinates of the semicircle f 1, g 2, &c.; then through the points 1, 2, 3, 4, &c., draw the curve D 5 E, which is the section required.

Again, let R S be the line of the required section; then from the points t, u, v, w, c, x, d, &c., where the concentric circles cut this line, draw the lines t 1, u 2, v 3, &c., perpendicular to R S, and transfer to them the corresponding ordinates of the semicircle; and through the points 1, 2, 3, 4, e, 5, f, &c., draw the curve R e f S, which is the section required.

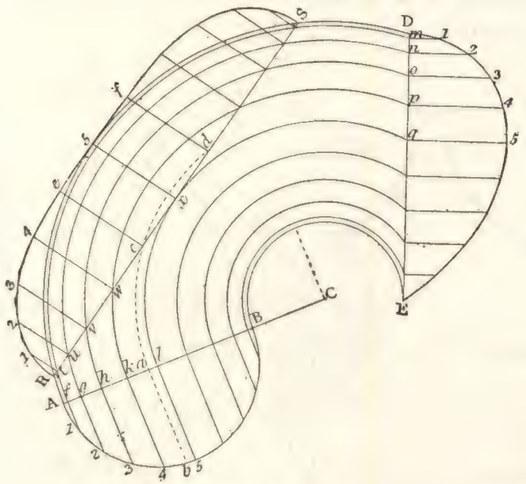


Fig. 52.

XLII. To describe the section of a solid of resolution the generating curve of which is an ogee.

Let A D B (Fig. 53) be half the plan or base of the solid, A a b B the vertical section through its axis, and E F the line of section required. From G draw C 5 perpendicular to E F, and bisecting it in m. In E m

take any number of points, g h k, &c., and through them draw the lines g 1, h 2, k 3, &c., perpendicular to E F. Then from C as a centre, through the points g, h, k, &c., draw concentric arcs cutting A B in r, s, t, u, v, and through these points draw the ordinates r 5, s 4, t 3, &c., perpendicular to A B. Transfer the heights of the ordinates on A B to the corresponding ordinates on each side of the centre of E F; and through the points 1, 2, 3, 4, 5, &c., draw the curve E 5 F, which is the section required.

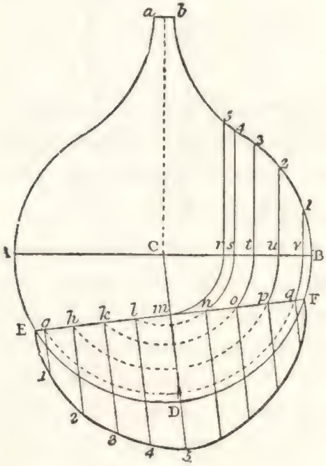


Fig. 53.

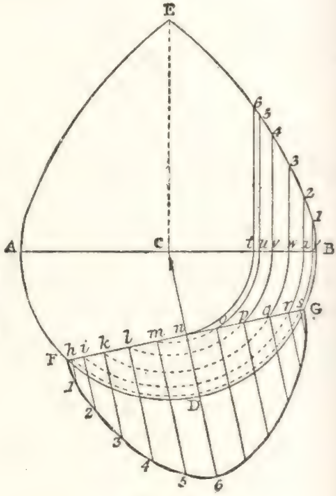


Fig. 54.

XLIII. To find the section of a solid of resolution, the generating curve of which is of a lancet form.

Let A D B (Fig. 54) be the plan of half the base, A E B the vertical section, and F G the line of the required section. The manner of finding the ordinates

and transferring the heights is precisely the same as in the last problem.

XLIV. To find the section of an ogee pyramid with a hexagonal base.

Let A D E F B (Fig. 55) be the plan of the base of the pyramid, A a b B a vertical section through its axis, and G H the line of the required section. Draw the arrises C D, C E, C F. On the line of section G H, at the points of intersection of the arrises with it, and

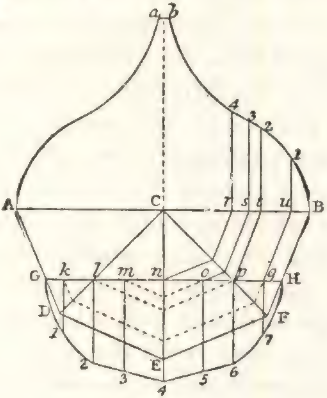


Fig. 55.

at some intermediate points k, m, o, q (the corresponding points k and q, and m and o, being equidistant from n), raise indefinite perpendiculars. Through these points k, l, m, n, o, p, q, draw lines parallel to the sides of the base, as shown by dotted lines; and from the points where these parallels meet the line A B, draw r 4, s 3, t 2, u 1, perpendicular to A B. These perpendiculars transferred to the ordinates n 4, m 3, o 5, l 2, p 6, k 1, q 7, will give the points 1, 2, 3, 4, 5, 6, 7, through which the section can be drawn.

6. INTERSECTIONS OF CURVED SURFACES.

When two solids having curved surfaces penetrate or intersect each other, the intersections of their surfaces form curved lines of various kinds. Some of these, as the circle, the ellipse, &c., can be obtained in the plane; but the others cannot, and are named curves of double curvature. The solution of the following problems depends chiefly on the knowledge of how to obtain, in the most advantageous manner, the projections of a point on a curved surface; and is in fact the application of the principles elucidated in the several previous problems. The manner of constructing the intersections of these curved surfaces which is the simplest and most general in its application, consists in conceiving the solids to which they belong as cut by planes according to certain conditions, more or less dependent on the nature of the surfaces. These section planes may be drawn parallel to one of the planes of the projection; and as all the points of intersection of the surfaces are found in the section planes, or on one of their projections, it is always easy to construct the curves by transferring these points to the other projection of the planes.

XLV. The projection of two equal cylinders which intersect at right angles being given, to find the projections of their intersections.

Conceive, in the horizontal projection (Fig. 56), a series of vertical planes cutting the cylinders parallel to their axis. The vertical projections of all the sections will be so many right-angled parallelograms, sim-

ilar to e f e f, which is the result of the section of the cylinder from surface to surface. The circumference of the second cylinder, whose axis is vertical, is cut by the same plane, which meets its upper surface at the two points g, h, and its under surface at two corresponding points. The vertical projections of these points are on the lines perpendicular to a b, raised on

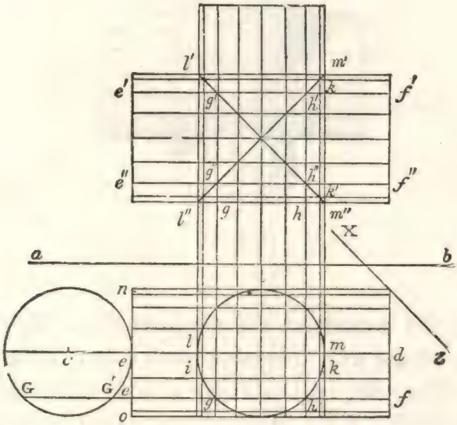


Fig. 56.

each of them, so that upon the lines e f, e f, will be situated the intersections of these lines at the points g, h, and g, h and the same with other points i, k, l, m. It is not necessary to draw a plan to find these projections. All that is actually required is to draw the circle representing one of the bases (as n o) of the cylinder laid flat on the horizontal plane. Then to produce g h till it cuts the circle at the superior and

inferior points G, G, and to take the heights e G, e G, and carry them, upon a b, from g to g g and from h to h, h.

Fig. 57 is the vertical projection made on the line x z.

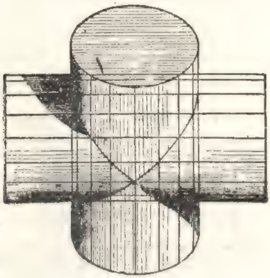


Fig. 57.

XLVI. To construct the projections of two unequal cylinders whose axis intersect each other obliquely.

Let A (Fig. 58) be the vertical projection of the two cylinders, and h S d e the horizontal projection of their axis. Conceive in the vertical projection, the cylinders cut by any number of horizontal planes; the horizontal projections of these planes will be rectangles as in the previous example, and their sides will be parallel to the axis of the cylinders.

The points of intersection of these lines will be the points sought. Without any previous operation, six of those points of intersection can be obtained. For example the point c is situated on d e, the highest point of the smaller cylinder; consequently, the horizontal projection of c is on d e, the horizontal projection of

d e, and it is also on the perpendicular let fall from c, that is to say, on the line c f parallel to the axis of the cylinder S h. The point sought will, therefore, be the intersection of those lines at c. In the same way i is

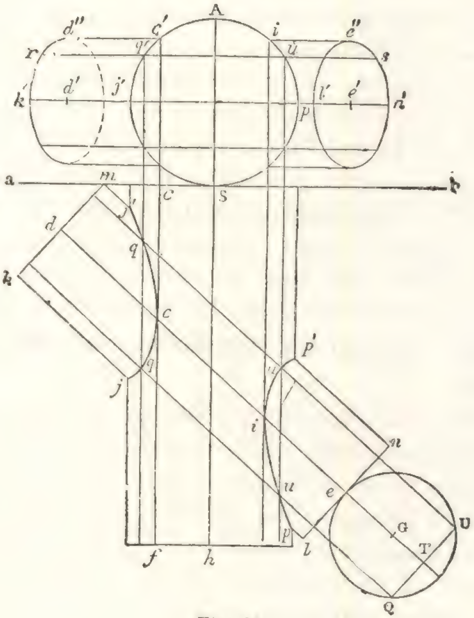


Fig. 58.

obtained. The point j is on the line k l, which is in the horizontal plane passing through the axis d e, the horizontal projections of k l are k l, and its opposite m n; therefore in letting fall perpendiculars from j p, the intersections of these with k l, m n, give the points j j,

p p. Thus six points are obtained. Take at pleasure an intermediate point q; through this point draw a line r s parallel to a b, which will be the vertical projection of a horizontal plane cutting the cylinder in q. The horizontal projection of this section will be, as in the preceding examples, a rectangle which is obtained by taking, in the vertical projection, the height of the section plane above the axis d e, and carrying it on the base in the horizontal projection from G to T. Through T is then to be drawn the line Q U perpendicular to G T; and through Q and U the lines parallel to the axis; and the points in which these lines are intersected by the perpendiculars let fall from q u are the intermediate points required. Any number of intermediate points can thus be obtained; and the curve being drawn through them, the operation is completed.

XLVII. To find the intersections of a sphere and a cylinder.

Let e f c d and i k g h (Fig. 59) be the horizontal projections of the sphere and cylinder respectively. Draw parallel to A B, as many vertical section planes are considered necessary, as e f, c d. These planes cut at the same time both the sphere and the cylinder, and the result of each section will be a circle in the case of the sphere, and a rectangle in the case of the cylinder. Through each of the points of intersection g, h, i, k, and from the centre l, draw indefinite lines perpendicular to A B. Take the radius of the circles of the sphere proper to each of these sections and with them, from the centre l, cut the correspondent perpendiculars in g g, h h, i i, &c., and draw through these points the curves of intersection.

XLVIII. To construct the intersection of two right cones with circular bases.

The solution of this problem is founded on the knowledge of the means of obtaining on one of the projections of a cone a point given on the other.

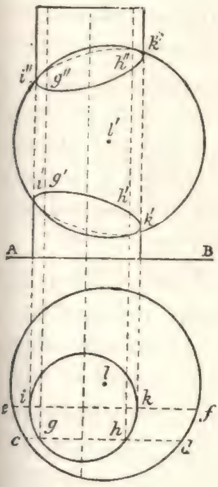


Fig. 59.

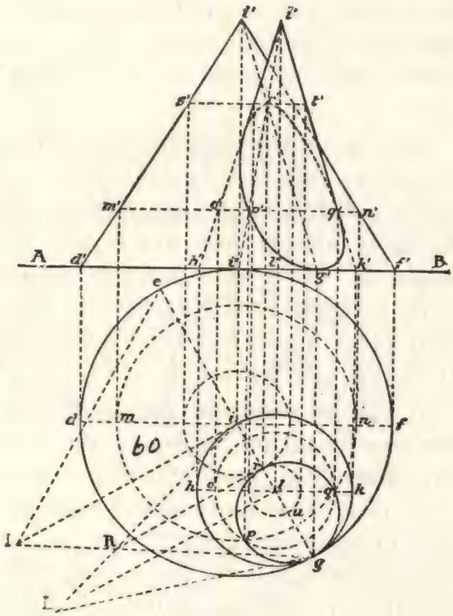


Fig. 60.

No. 1. Let A B (Fig. 60) be the common section of the two planes of projection, the circles g d e f and g h i k the horizontal projections of the given cones, and the triangles d i f and h l k their vertical projections. Suppose these cones cut by a series of horizontal planes: each section will consist of two circles, the

intersections of which will be points of intersection of the conical surfaces. For example, the section made by a plane m n will have for its horizontal projections two circles of different diameters, the radius of the one being i m, and of the other l o. The intersecting points of these are p and q, and these points are common to the two circumferences; and their vertical projection on the plane m n will be p q. Thus, as many points may be found as is necessary to complete the curve.

But there are certain points of intersection which cannot be rigorously established by this method without a great deal of manipulation. The point r in the figure is one of those; for it will be seen that at that point the two circles must be tangents to each other, and it would be difficult to fix the place of the section plane s t so exactly by trial, that it would just pass through the point.

It will be seen that the point r must be situated in the horizontal projection of the line g i a perpendicular i l equal to the height of the cone. From one raise a perpendicular and make it equal to the height of the second cone, and draw its side L i; and from the point of intersection R let fall a perpendicular on g i meeting it in r; through r draw an indefinite line perpendicular to A B, and set up on it from A B to r the height r R. The point r can also be obtained directly in the vertical projection by joining i g and l i as shown.

Bisect r g in u, and from u as a centre, with the radius u r, describe a circle, the circumference of which will be the horizontal projection of the intersec-

tion of the two cones. The vertical projection of this circle will be g p r q, and can be found by the method indicated above.

No. 2. Conceive the horizontal projection (Fig. 61, No. 1) a vertical plane C D cutting both cones through their axis: the sections will be two triangles, having

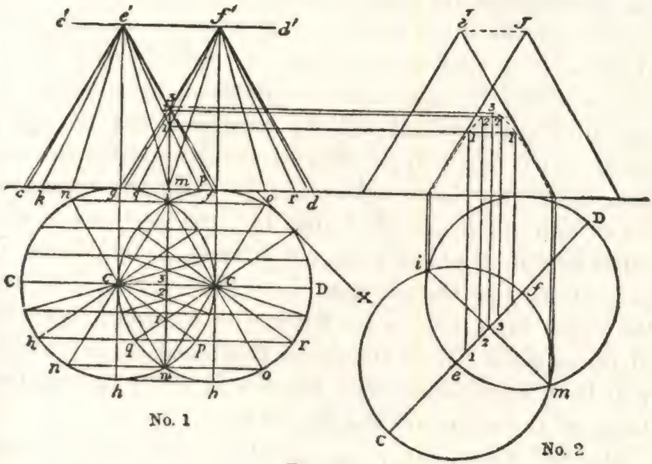


Fig. 61.

the diameters of the bases of the cones as their bases, and the height of the cones as their height. And as in the example the cones are equal, the triangles will also be equal, as the triangles c e f, g f d, in the vertical projection. Conceive now a number of inclined planes, as c n m, c k p, &c., passing through the different points of the base, but still passing through the summits of the cones; the sections which result will still be triangles (as has already been demonstrated), whose bases diminish in proportion as the planes re-

cede from the centres of the bases of the cones, until at length the plane becomes a tangent to both cones and the result is a tangent line whose projections are h c, h c, g e, f f. It will be observed that the circumferences of the bases cut each other at m and i, which are the first points of their intersections, whose vertical projections are the point m merely. If the projections of the other points of intersection on the lines of the section planes are found (an operation presenting no difficulty, and easily understood by the inspection of the figure), it will be seen that the triangles n c m, m c o, k e p, q e r, &c., in the horizontal projection, have for their vertical projections the triangles n e m, m o, k e p, &c., and that the intersections of the cones are in a plane perpendicular to both planes of projection, and the projections of the intersections are the right lines i m, m 3. From the known properties of the conic sections, the curve produced by this plane will be a hyperbola. Fig. 61, No. 2, gives the projections of the cones on the line o x.

No. 3. The next example (Fig. 62) differs from the last in the inequality of the size of the cones. Suppose an indefinite line C D to be the horizontal projection of the vertical section plane, cutting the two cones through their axis e f. Conceive in this plane an indefinite line e f D, passing through the summits of the cones, the vertical projection of this line will be e f d: from d let fall on C D a perpendicular meeting it in D; this will be the point in which the line passing through the summits of the cones will meet the horizontal plane; and it is through this point, and through the summits e and f, that the inclined section planes should

be made to pass. The horizontal traces of these planes are O D, G D, &c.: O D is then the trace of a tangent plane to the two conical surfaces O e, P f; and the plane e G D cuts the greater cone, and forms by the section the triangles G e H in the horizontal, and g e h in the vertical projection; and it cuts the lesser cone, and forms the triangles I f J, i f j. In the horizontal

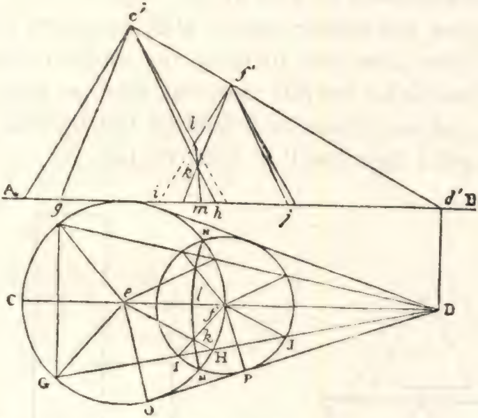


Fig. 62.

projection it is seen that the sides H e, I f of the triangles intersect in k, which is therefore the horizontal projection of one of the points of intersection; and its vertical projection is k. In the same manner, other points can be found. It is seen at once that M, N, l, are also points in the intersection. The curves traced through the points M k l N in the horizontal, and m k l in the vertical projection, are the projections of the intersection of the two cones.

7. COVERINGS OF SOLIDS.

1. Regular Polyhedrons. A solid angle cannot be formed with fewer than three plane angles. The simplest solid is, therefore, the tetrahedron or pyramid having an equilateral triangle for its base, and its other three sides formed of similar triangles.

The development of this figure (Fig. 63) is made by drawing the triangular base A B C, and then drawing around it the triangles forming the inclined sides. If the diagram is on flexible material, such as paper, then cut out, and the triangles folded on the lines A B, B C, C A, the solid figure will be constructed.

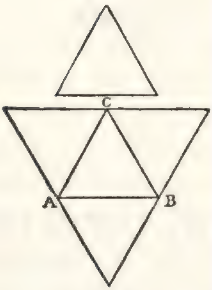


Fig. 63.

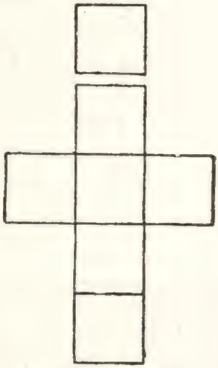


Fig. 64.

The **hexahedron,** or cube, is composed of six equal squares (Fig. 64); the **octahedron** (Fig. 65) of eight equilateral triangles; the **dodecahedron** (Fig. 66) of twelve pentagons; the **icosahedron** (Fig. 67) of twenty

equilateral triangles. In these figures, A is the elevation and B the development.

The elements of these solids are the equilateral triangle, the square, and the pentagon. The irregular polyhedrons may be formed from those named, by cutting off the solid angles. Thus, in cutting off the

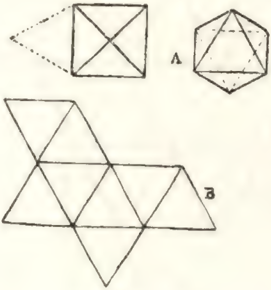


Fig. 65.

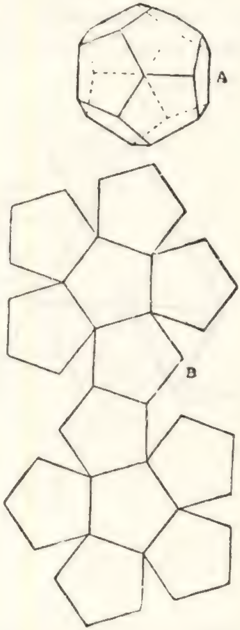


Fig. 66.

angles of the tetrahedron, there results a polyhedron of eight faces, composed of four hexagons and four equilateral triangles. The cutting off the angles of the cube, in the same manner gives polyhedron of four-

teen faces, composed of six octagons, united by eight equilateral triangles.

The same operation performed on the octahedron produces fourteen faces, of which eight are hexagonal and six square; on the dodecahedron it gives thirty-two sides, namely, twelve decagons, and twenty triangles; on the icosahedron it gives thirty-two sides—twelve tentagons and twenty hexagons. This last approaches almost to the globular form and can be rolled like a ball.

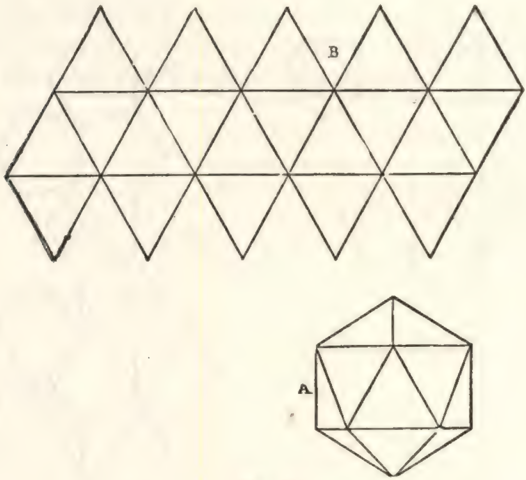


Fig. 67.

The other solids which have plane surfaces are the pyramids and prisms. These may be regular and irregular: they may have their axis perpendicular or inclined; they may be truncated or cut with a section, parallel or oblique, to their base.

II. Pyramids. The development of a right pyramid, of which the base and the height are given, offers no difficulty. The operation consists (Fig. 68) in elevating on each side of the base, a triangle having its height equal to the inclined height of each side, or, otherwise, connecting the sides, together as shown by the dotted lines.

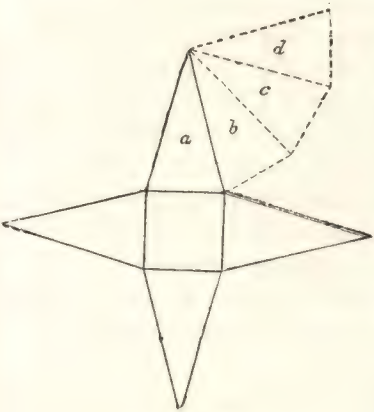


Fig. 68.

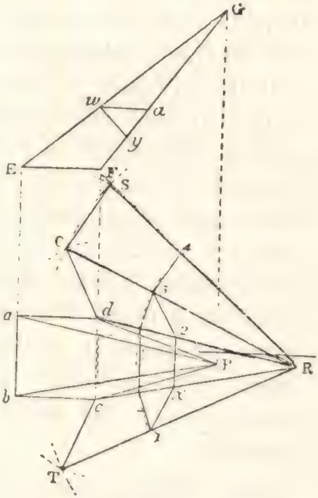


Fig. 69.

In an oblique pyramid the development is found as follows: Let a b c d (Fig. 69) be the plan of the base of the pyramid, a b c d its horizontal projection, and E F G its vertical projection. Then on the side d c construct the triangle c R d, making its height equal to the sloping side of the pyramid F G. This triangle is the development of the side d P c of the pyramid.

Then from d, with the radius E F, describe an arc O; and from R, with the radius equal to the true length e G of the arris E G, describe another arc intersecting the last at O. Join R O, d O; the triangle d R O will be the development of the side a P d. In the same way, describe the triangle c R T, for the development of the side b P c. From R, again, with the same radius R O, describe an arc S, which intersect by an arc described from O with the radius a b; and the triangle O R S will be the development of the side a P b.

If the pyramid is truncated by a plane w a parallel to the base, the development of that line is obtained by setting off from R on R c, and R d, the true length of the arris G a in x and 2, and on R S, R O, and R T, the true length of the arris G w in 4, 3, 1; and drawing the lines 1 x, x2, 2 3, 3 4, parallel to the base of the respective triangles T R c, c R d, d R O, O R S. If it is truncated by a plane w y, perpendicular to the axis, then from the point R, with the radius equal to the true length of the arris G w, or G y, describe an arc 1 4, and inscribe in it the sides of the polygon forming the pyramid.

III. Prisms. In a right prism, the faces being all perpendicular to the bases which truncate the solid, it results that their development is a rectangle composed of all the faces joined together, and bounded by two parallel lines equal in length to the contour of the bases. Thus, in Fig. 70, a b c d is the base, and b e the height of the prism; the four sides will form the rectangle b e f g, and e h i k will be the top of the prism. The full lines show another method of development.

When a prism is inclined, the faces form different

angles with the lines of the contours of the bases: whence there results a development, the extremities of which are bounded by lines forming parts of polygons.

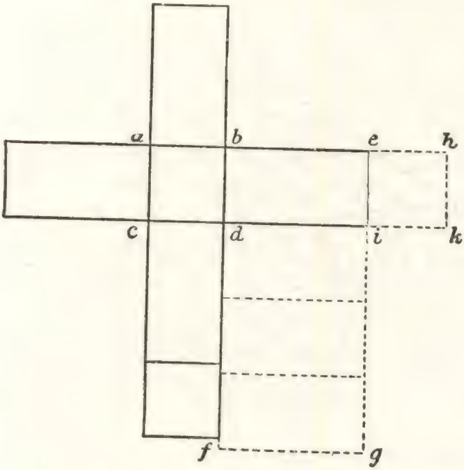


Fig. 70.

After having drawn the line C C (Fig. 71), which indicates the axis of the prism and the lines A B, D E, the surfaces which terminate it, describe on the middle of the axis the polygon forming the plan of the prism, taken perpendicularly to the axis, and indicated by the figures 1 and 8. Produce the sides 1 2, 6 5, parallel to the axis, until they meet the lines A B, D E. These lines then indicate the four arrises of the prism, corresponding to the angles 1 2 5 6. Through the points

8 3 7 4 draw lines parallel to the axis meeting A B, D E in F H, G L. These lines represent the four arrises 8 3 7 4.*

In this profile the sides of the plan of the polygon 1 2 3 4 5 6 7 8 give the width of the faces of the prism

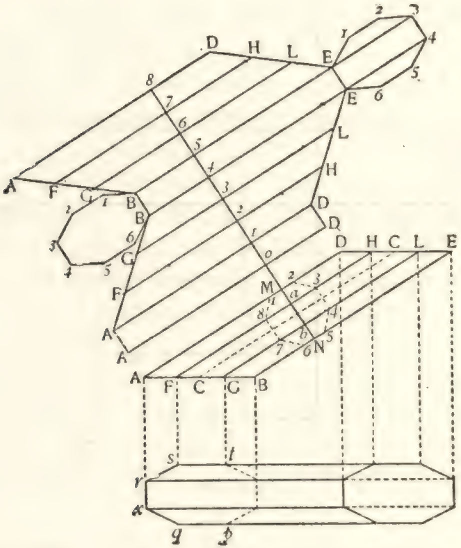


Fig. 71.

and the lines A D, F H, G L, B E their length. From this profile can be drawn the horizontal projection, in the manner shown below. To trace the development of this prism on a sheet of paper, so that it can be folded

*In Fig. 75 another example is given, but as the method of procedure is the same as in Fig. 71, detailed description is unnecessary.

together to form the solid, proceed thus: On the middle of C C raise an indefinite perpendicular M N. On that line set off the width of the faces of the prism, indicated by the polygon, in the points 0 1 2 3 4 5 6 7 8. Through these points draw lines parallel to the axis, and upon them set off the lengths of the lines in profile, thus: From the points O, 1, and 8, set off the length M D in the points D D D; from 2 and 7, set off a H in H; from 3 and 6, set off b L in L and L; and so on. Draw the lines DD, D H L E, EE, E L H D, for the contour of the upper part of the prism. To obtain the contour of the lower portion, set off the length M A from O, 1, and 8 to A A A, the length a F from 2 and 7 to F and F, the length b G from 3 and 6 to G and G, and so on; and draw A A, A F G B, B B, B G F A, to complete the contour. The development is completed by making on B B and E E the polygons 1 2 3 4 5 6 BB, 1 2 3 4 5 6 EE, similar to the polygons of the horizontal projection.

IV. Cylinders. Cylinders may be considered as prisms, of which the base is composed of an infinite number of sides. Thus we shall obtain graphically the development of a right cylinder by a rectangle of the same height, and of a length equal to the circumference of the circle, which serves as its base.

To find the covering of a right cylinder.

Let A B C D (Fig. 72) be the seat or generating section. On A D describe the semicircle A 5 D, representing the vertical section of half the cylinder, and divide its circumference into any number of parts, 1, 2, 3, 4,

5, &c., and transfer those divisions to the lines A D and B C produced; then the parallelogram D C G F will be the covering of one half the cylinder.

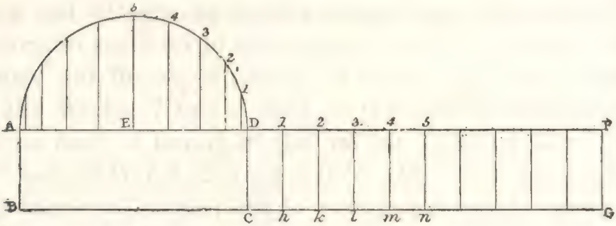


Fig. 72.

To find the edge of the covering when it is oblique in regard to the sides of the cylinder.

Let A B C D (Fig. 73) be the seat of the generating section, the edge B C being oblique to the sides A B, D C. Draw the semicircle A 5 D, and divide it into any

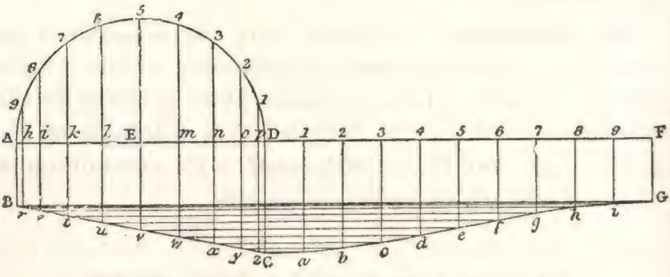


Fig. 73.

number of parts as before; and through the divisions draw lines at right angles to A D, producing them to meet B C in r s, t, u, v, &c. produce A D, and the lines 1 a, 2 b, 3 c, &c., perpendicular to D F. To these lines

transfer the length of the corresponding lines intercepted between A D and B C, that is, to 1a transfer the length p z, to 2 b transfer o y, and so on, by drawing the lines z a, y b, x c, &c., parallel to A F. Through the points thus obtained, draw the curved line C a b c, &c., to G; then shall D F C G be the development of the covering of the semi-cylinder A B C D.

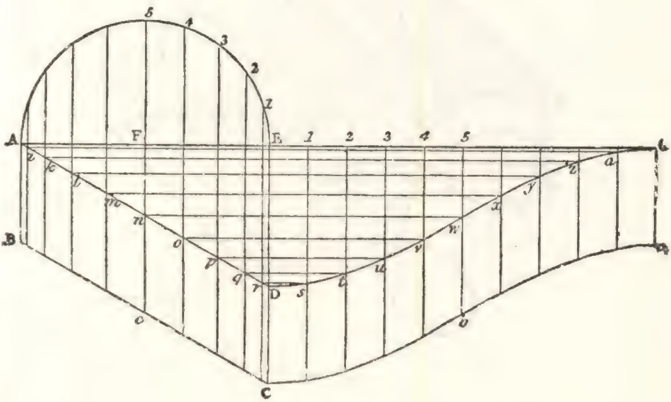


Fig. 74

To find the covering of a cylinder contained between two oblique parallel planes.

Let A B C D (Fig. 74) be the seat of the generating section. From A draw A G perpendicular to A B, and produce C D to meet it in E. On A E describe the semicircle, and transfer its perimeter to E G, by dividing it into equal parts, and setting off corresponding divisions on E G. Through the divisions of the semicircle draw lines at right angles to A E, producing them to

meet the lines A D and B C, in i, k, l, m, &c. Through the divisions on E G draw lines perpendicular to it; then through the intersections of the ordinates of the semicircle, with the line A D, draw the lines i a, k z, l y,

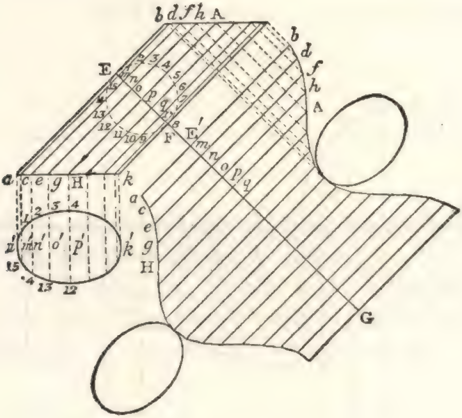


Fig 75.

&c., parallel to A G and where these intersect the perpendiculars from E G, in the points a, z, y, x, w, u. &c., trace a curved line G D, and draw parallel to it the curved line H C; then will D C H G be the development of the covering of the semi-cylinder A B C D.

To find the covering of a semi-cylindric surface bounded by two curved lines.

The construction to obtain the developments of these coverings (Figs. 76 and 77) is precisely similar to that described in Fig. 74.

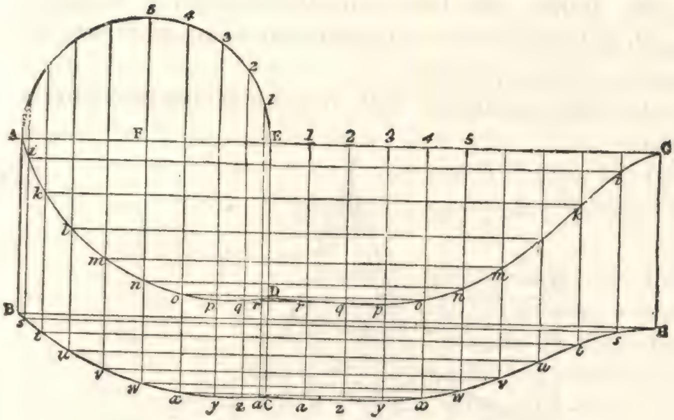


Fig. 76.

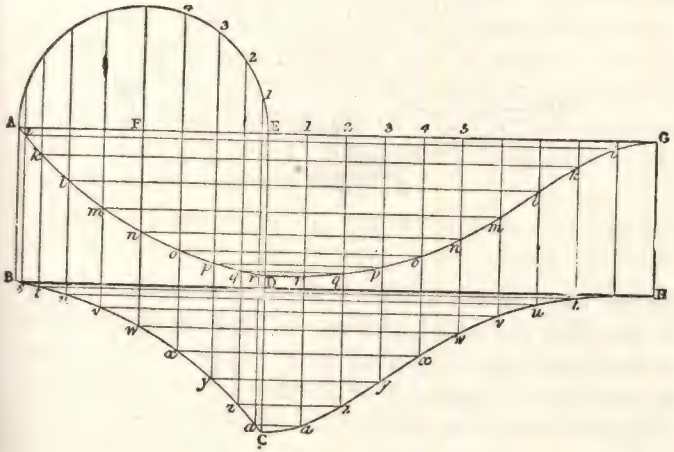


Fig. 77.

V. Cones. We have considered cylinders as prisms with polygonal bases. In a similar manner we may regard cones as pyramids.

In right pyramids, with regular symmetrical bases,

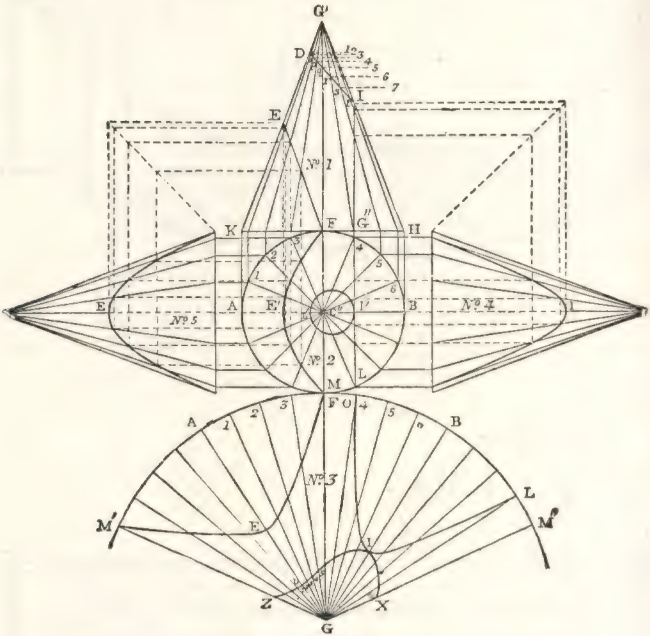


Fig. 78.

as the lines of the arrises extending from the summit to the base are equal, and as the sides of the polygons forming the base are also equal, their developed surfaces will be composed of similar and equal isosceles triangles, which, as we have seen (Fig. 78, a, b, c, d), will, when united, form a part of a regular polygon

inscribed in a circle, of which the inclined sides of the polygon form the radii. Thus in considering the base of the cone K H (Fig. 78) as a regular polygon of an infinite number of sides, its development will be found in the sector of a circle, M A F B M (No. 3), of which the radius equals the side of the cone K G (No. 1), and the arc equals the circumference of the circle forming its base (No. 2).

To trace on the development of the covering, the curves of the ellipse, parabola, and hyperbola, which are the result of the sections of the cone by the lines D I, E F, I G, it is necessary to divide the circumference of the base A F B M (No. 2) into equal parts, as 1, 2, 3, &c., and from these to draw radii to the centre C, which is the horizontal projection of the vertex of the cone; then to carry these divisions to the common intersection line K H, and from their terminations there to draw lines to the vertex G, in the vertical projection No. 1. These lines cut the intersecting planes, forming the ellipse, parabola, and hyperbola, and by the aid of the intersections we obtain the horizontal projection of these figures in No. 2—the parabola passing through M E F, the hyperbola through G I L, and the ellipse through D I.

To obtain points in the circumference of the ellipse upon the development, through the points of intersection o, p, q, r, &c., draw lines parallel to K H, carrying the heights to the side of the cone G H, in the points 1, 2, 3, 4, 5, 6, 7, and transfer the lengths G 1, G 2, G 3, &c. to G 1, G 2, G 3, G 4, &c., on the radii of the development in No. 3; and through the points thus obtained draw the curve z D 1 X.

To obtain the parabola and hyperbola, proceed in the same manner, by drawing parallels to the base K H, through the points of intersection; and transferring the lengths thus obtained on the sides of the cone G K, G H, to the radii in the development.

Nos. 4, and 5 give the vertical projections of the hyperbola and parabola respectively.

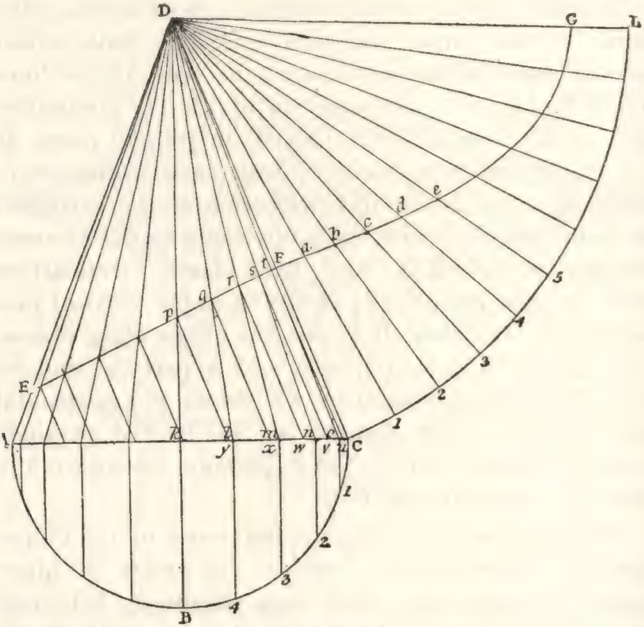


Fig. 79.

To find the covering of the frustum of a cone, the section being made by a plane perpendicular to the axis.

Let A C E F (Fig. 79) be the generating section of

the frustum. On A C describe the semi-circle A B C, and produce the sides A E and C F to D. From the centre D, with the radius D C, describe the arc C H; and from the same centre with the radius D F, describe

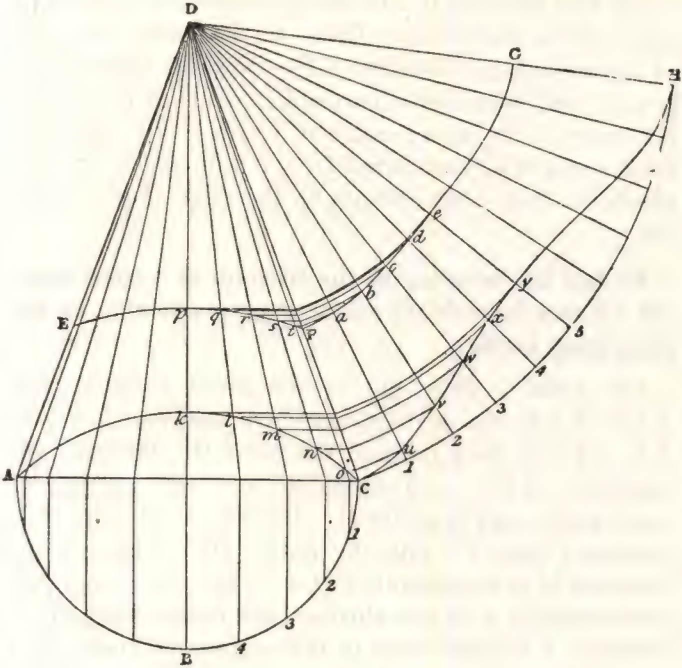


Fig. 80.

the arc F G. Divide the semicircle A B C into any number of equal parts, and run the same divisions along the arc C H; draw the line H D, cutting E G in G; then shall C H G F be half the development of the covering of the frustum A C F E.

To find the covering of the frustum of a cone, the section being made by a plane not perpendicular to the axis.

Let A C F E (Fig. 80) be the frustum. Proceed as in the last problem to find the development of the covering of the semi-cone. Then—to determine the edge of the covering of the line E F—from the points P, q, r, s, t, &c., draw lines perpendicular to E F, cutting A C in y, x, w, v, u; and the length u t transferred from 1 to a, v s, transferred from 2 to b, and so on, will give a, b, c, d, e, &c., points on the edge of the covering.

To find the covering of the frustum of a cone, when cut by two cylindrical surfaces perpendicular to the generating section.

Let A E F C (Fig. 81) be the given frustum, and A k C, E p F, the given cylindrical surfaces. Produce A E, C F, till they meet in the point D. Describe the semicircle A B C, and divide it into any number of equal parts, and transfer the divisions to the arc C H, described from D, with the radius D C. Through the divisions in the semicircle 1, 2, 3, 4, &c., draw lines perpendicular to A C, and through the points where they intersect A C draw lines to the summit D. Draw lines also through the points 1, 2, 3, 4, 5, &c., of the arc C H, to the summit D; then through the intersections of the lines from A C to D, with the seats of the cylindrical surfaces k, l, m, n, o, and p, q,r, s, t, draw lines parallel to A C, cutting C D; and from the points of intersection in C D and from the centre D, describe arcs cutting the radial lines in the sector D C H in u, v, w, x, y,

&c., and a, b, c, d, e, &c., and curves traced through the intersections will give the form of the covering.

VI. Spheres, Ellipsoids, &c. The development of the sphere, and of other surfaces of double curvature,

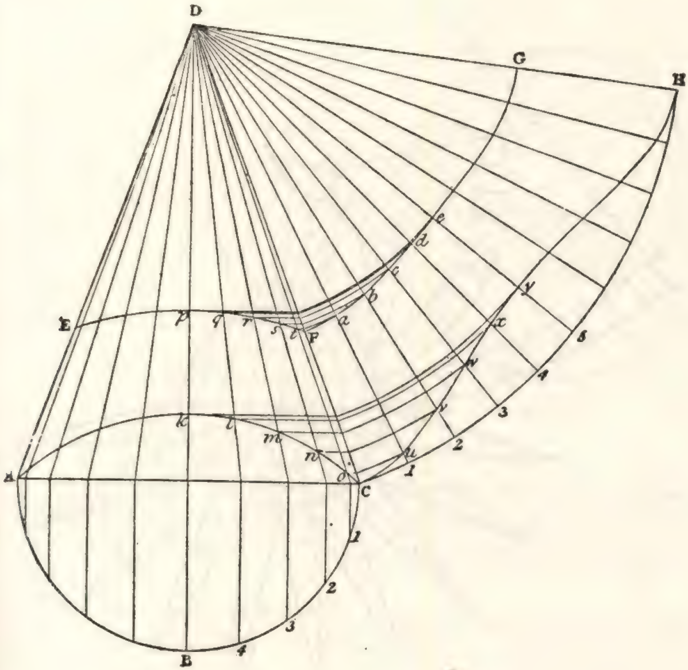


Fig. 81.

is impossible, except on the supposition of their being composed of a great number of small faces, either plane, or of a simple curvature, as the cylinder and the

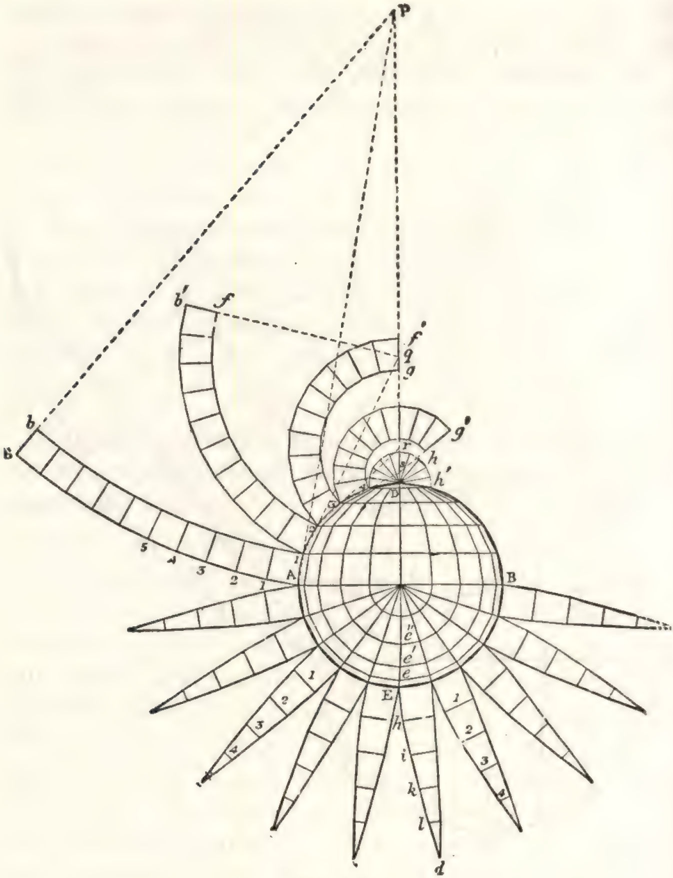


Fig. 82.

cone. Thus, the sphere or spheroid may be considered as a polyhedron, terminated, 1st, by a great number of plane faces, formed by truncated pyramids, of which the base is a polygon, as in Fig. 82; 2nd, by parts of

truncated cones forming zones, as in Fig. 83, the part above A B being the vertical projection, and the part below A B the horizontal projection; 3rd, by parts of cylinders cut in gores, forming flat sides, which diminish in width, as in Fig. 84.

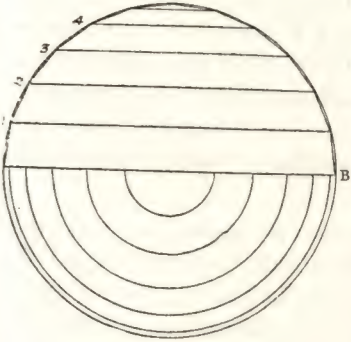


Fig. 83.

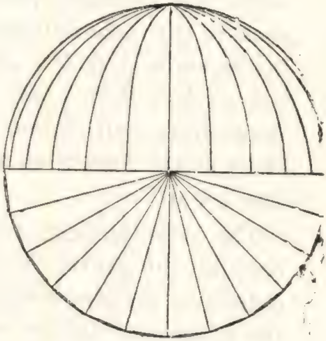


Fig. 84.

In reducing the spheres, or spheroid, to a polyhedron with flat sides, two methods may be adopted, which differ only in the manner of arranging the developed faces.

The most simple method is by parallel circles, and others perpendicular to them, which cut them in two opposite points, as in the lines on a terrestrial globe. If we suppose that these divisions, in place of being circles, are polygons of the same number of sides, there will result a polyhedron, like that represented in Fig. 82, of which the half, A D B, shows the geometrical elevation, and the other half, A E B, the plan.

To find the development, first obtain the summits

P, q, r, s, of the truncated pyramids, which from the demi-polyhedron A D B, by producing the sides A 1, 12, 23, 34, until they meet the axis E D produced; then from the points p, q, r, s, and with the radii P A, P I, q I q 2, r 2, r 3, and s 3, s 4, describe the indefinite arcs A B, 1 b, 1 b, 2 f, 2 f, e q, 3 g, 4 h, and from D describe the arc 4 h; upon all these arcs set off the divisions of the demi-polygons A E B, and draw the lines to the summits p, q, r, s, and D, from all the points so set out, as A, 1, 2, 3, 4, &c., from each truncated pyramid. These lines will represent for every band or zona the faces of the truncated pyramids of which they constitute a part.

The development can also be made by drawing through the centre of each side of the polygon A E B, indefinite perpendiculars, and setting out upon them the heights of the faces in the elevation, A1 2 3 4 D, and through the points thus obtained drawing parallels to the base. On each of these parallels then set out the widths, h, i, k, l, d, of the corresponding faces (e, e, e, &c.) in the plan, and there will be thus formed trapeziums and triangles, as in the first development, but arranged differently. This method is used in constructing geographical globes, the other is more convenient in finding the stones of a spherical dome.

The development of the sphere by reducing it to conical zones (Fig. 83) is accomplished in the same manner as the reduction to truncated pyramids, with this difference, that the developments of the arrises, indicated by A 1 2 3 4 5 B in Fig. 82, are arcs of circles described from the summits of cones, in place of being polygons.

The development of the sphere reduced into parts of cylinders, cut in gores (Fig. 84), is produced by the second method described, but in place of joining, by straight lines, the points E, h, i, k, l, d (Fig. 82), we

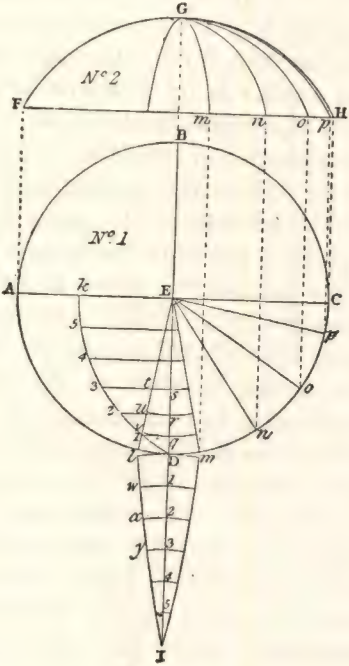


Fig. 85.

unite them by curves. This last method is used in tracing the development of caissons in spherical or spheroidal vaults.

To find the covering of a segmental dome.

In Fig. 85, No. 1 is the plan, and No. 2 the elevation of a segmental dome. Through the centre of the plan

E draw the diameter A C, and the diameter B D perpendicular to A C, and produce B D to I. Let D E represent the base of semi-section of the dome; upon D E describe the arc D k with the same radius as the arc F G H (No. 2); divide the arc D k into any number of equal parts, 1, 2, 3, 4, 5, and extend the division upon the right line D I, making the right line D I equal in length, and similar in its divisions, to the arc D k: from the points of division, 1, 2, 3, 4, 5, in the arc D k, draw lines perpendicular to D E, cutting it in the points q, r, s, &c. Upon the circumference of the plan No. 1, set off the breadth of the gores or boards l m, m n, n o, o p, &c.; and from the points l, m, n, o, p, draw right lines through the centre E: from E describe concentric arcs q v, r u, st, &c., and from l describe concentric arcs through the points D, 1, 2, 3, 4, 5,: l m, being the given breadth of the base, make l w equal to q v, 2x equal to r u, 3 y equal to st, &c.; draw the curved line through the points l, w, x, y, &c., to l, which will give one edge of the board or gore to coincide with the line l E. The other edge being similar, it will be found by making the distances from the centre line D 1 respectively equal. The seats of the different boards or gores on the elevation are found by the perpendicular dotted lines, pp, oo, nn, m m, &c.

To find the covering of a semicircular dome.

Fig. 86, Nos. 1 and 2.—The procedure here is more simple than in the case of the segmental dome, as, the horizontal and vertical sections being alike, the ordinates are obtained at once.

To find the covering of a semicircular dome when it is required to cover the dome horizontally.

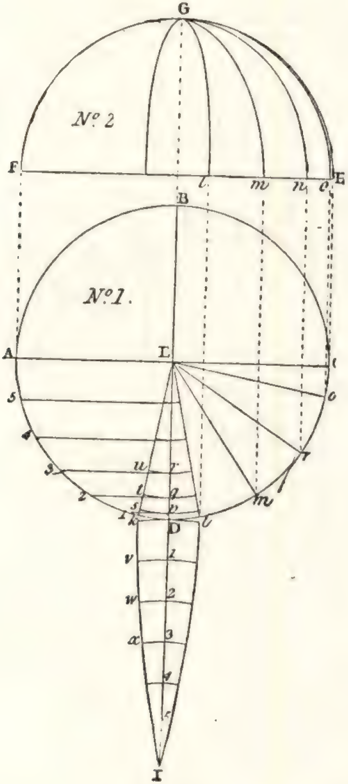


Fig. 86.

Let A B C (Fig. 87) be a vertical section through the axis of a circular dome, and let it be required to cover this dome horizontally. Bisect the base in the point

D, and draw D B E perpendicular to A C, cutting the circumference in B. Now divide the arc B C into equal parts, so that each part will be rather less than

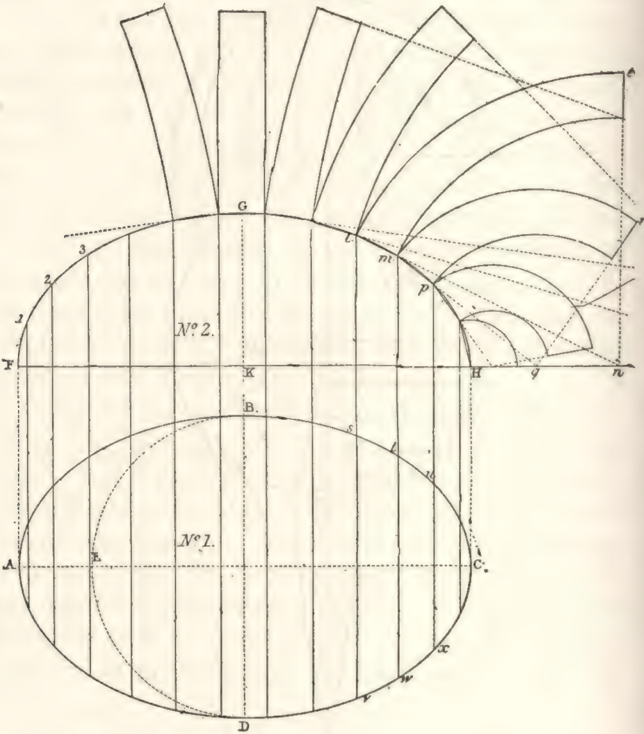


Fig. 87.

the width of the a board; and join the points division by straight lines, which will form an inscribed polygon of so many sides; and through these points draw line parallel to the base A C, meeting the opposite sides of

the circumference. The trapezoids formed by the sides of the polygon and the horizontal lines may then be regarded as the sections of so many frustums of cones; whence results the following mode of procedure, in

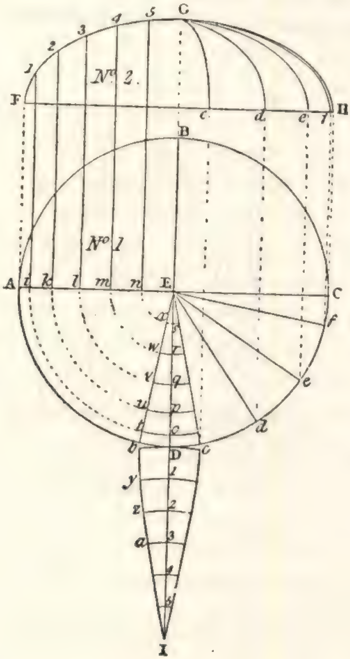


Fig. 85.

accordance with the introductory illustration Fig. 82; —Produce, until they meet the line D E, the lines g f, f, n, &c., forming the sides of the polygon. Then, to describe a board which corresponds to the surface of one of the zones, as f g, of which the trapezoid m l f g is a

section,—from the point h, where the line f g produced meets D E, with the radii h f, hg, describe two arcs, and cut off the end of the board k on the line of a radius h k.

To obtain the true length of the board, proceed as in Fig. 89. The other boards are described in the same manner.

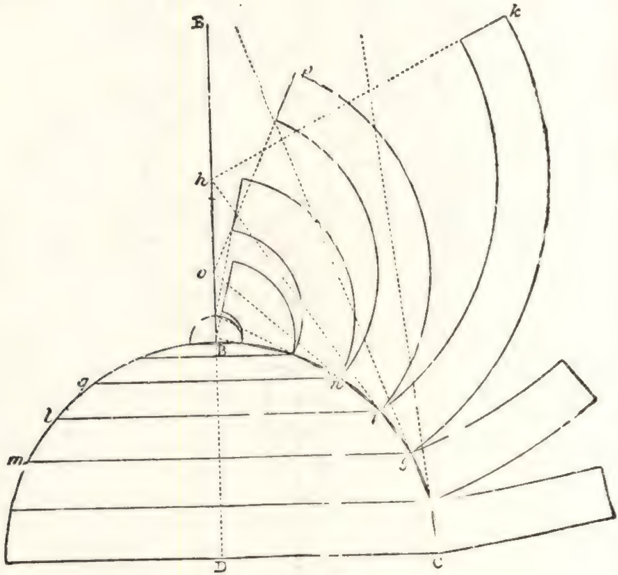


Fig. 89.

To find the covering of an elliptic dome.

Let A B C D (Fig. 90) be the plan, and F G H the elevation of the dome. Divide the elliptical quadrant F G (No. 2) into any number of equal parts in 1, 2, 3, 4. 5, and draw through the points of division lines

perpendicular to F H, and produced to A C (No. 1), meeting it in i, k, m, n,: these divisions are transferred by the dotted arcs to the gore b E c and the remainder of the process is as in Figs. 85 and 86.

To find the covering boards of an ellipsoidal dome.
Let A B C D (No. 1, Fig. 89) be the plan of the dome, and F G H (No. 2) the vertical section through its major axis. Produce F H indefinitely to n; divide the circumference, as before, into any number of equal parts, and join the divisions by straight lines, as p m, ml, &c. Then, describe on a board, produce the line forming one of the sides of the polygon, such as l m, to meet F n in n; and from n, with the radii n m, n l describe two arcs forming the sides of the board, and cut off the board on the line of the radius n o. Lines drawn through the points of divisions at right angles to the axis, until they meet the circumference A D C of the plan, will give the plan of the boarding.

To find the covering of an ellipsoidal dome in gores.

Let the ellipse A B C D (Fig. 90, No. 1) be the plan of the dome, A C its major axis and B D its minor axis; and let A B C (No. 2) be its elevation. Then, first, to describe on the plan and elevation the lines of the gores, proceed thus:—Through the line A C (No. 1) produced at H, draw the line E G perpendicular to it, and draw B E, D G, parallel to the axis A C, cutting E G, then will E G be the length of the axis minor, on which is to be described the semi-circle E F G, representing a section of the dome on a vertical plane passing through the axis minor.

Divide the circumference of the semi-circle into any number of equal parts, representing the widths of the

covering boards on the line B D; and through the points of division 1, 2, 3, 4, 5, draw lines parallel to the axis A C, cutting the line B D in 1, 2, 3, 4, 5. Divide the quadrant of the ellipse C D (No. 1) into any number of equal parts in e, f, g, h, and through these points draw the lines e a, f b, g c, h d in both diagrams, per

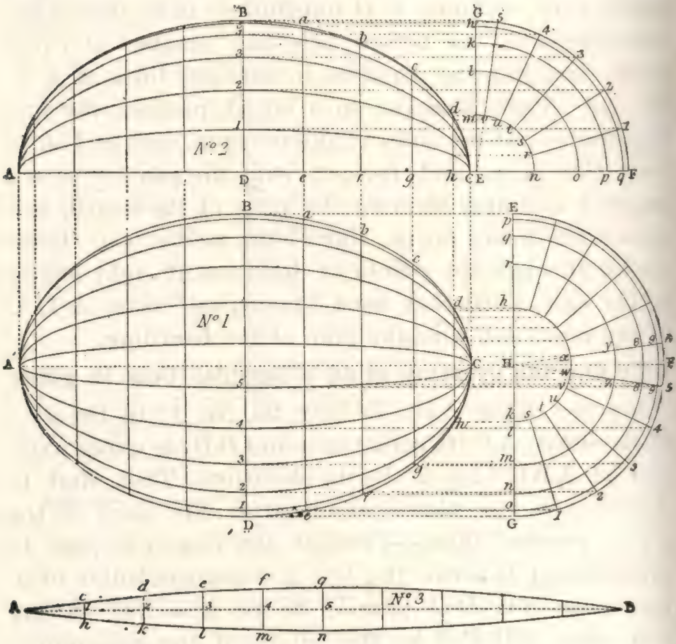


Fig. 90.

pendicular to A C, and these lines will then be the seats of vertical sections through the dome, parallel to E F G. Through the points e, f, g, h (No. 1) draw lines parallel to the axis A C, cutting E G in o, n, m, k;

and from H, with the radii H o, H n, H m, H k, describe concentric circles o 9 9 p, n 8 8q, m z y r, &c. To find the diminished width of each gore at the sections a, e, b f, c g, d h:—Through the divisions of the semicircle, 1, 2, 3, 4, 5, draw the radii ls, 2t, 3u, 4v, 5w, 6x; then by drawing through the intersections of these radii with the concentric circles, lines parallel to H F, to meet the section lines corresponding to the circles, the width of the gores at each section will be obtained; and curves through these points will give the representation of the lines of the gores of the plan.

In No. 2 the intersections of the lines are more clearly shown. The quadrant E G F is half the end elevation of the dome, and is divided as in No. 1. The parallel lines 5 5, 4 4, 3 3, show how the divisions of the arc of the quadrant are transferred to the line D B, and the other parallels a h, b k, cl, d m, are drawn from the divisions in the circumference of the ellipse to the line E G, and give the radii of the arcs m, l o, k p, h q.

To describe one of the gores draw any line A B (No. 3), and make it equal in length to the circumference of the semi-ellipse A D C, by setting out on it the divisions 1, 2, 3, 4, 5, &c., corresponding to the divisions C h, h g, g f, &c., of the ellipse: draw through those divisions lines perpendicular to A B. Then from the semi-circle (No. 1) transfer to these perpendiculars the widths 6 5 to g n, 9 9 to f m, 8 8 to e l, y z to d k, and x w to c h, and join A c, d d, de, e f, f g, A h, h k, k l, l m, and m n,; which will give the boundary lines of one-half of the gore, and the other half is obtained in the same manner.

To describe the covering of an ellipsoidal dome with horizontal boards of equal width.

Let A B C D (No. 1, Fig. 91) be the plan of the dome, A B C (No. 2) the section on its major axis, and L M N the section on its minor axis. Draw the circumscribing parallelogram of the ellipse, namely, F G H K (No. 1), and its diagonals F H G K. In No. 2 divide the circumference into equal parts, 1, 2, 3, 4, representing the number of covering boards, and through the points of division draw lines 1 8, 2 7, &c., parallel to A C. Through the points of divisions draw 1 p, 2 t, 3 x, &c., perpendicular to A C, cutting the diagonals of the circumscribing parallelogram of the ellipse (No. 1), and meeting its major axis in p, t, x, &c. Complete the parallelograms, and inscribe ellipses therein corresponding to the lines of the covering. Produce the sides of the parallelograms to intersect the circumference of the section on the minor axis of the ellipse in 1, 2, 3, 4, and lines drawn through these parallel to L N, will give the representation of the covering boards in that section. To find the development of the cover ing, produce the axis D B, in No. 2, indefinitely. Join by a straight line the divisions 1 2 in the circumference, and produce the line indefinitely, making e k equal to e 2, and k g equal to 1 2; 1 2e k g will be the axis major of the ellipses of the covering 1 2 7 8. Join also the corresponding divisions in the circumference of the section on the minor axis, and produce the line 1 2 b to meet the axis produced; and the length of this line will be the semi-axis minor, e h, of the ellipse, 2 h k, while the width f h will be equal to the division 12 in N M L.

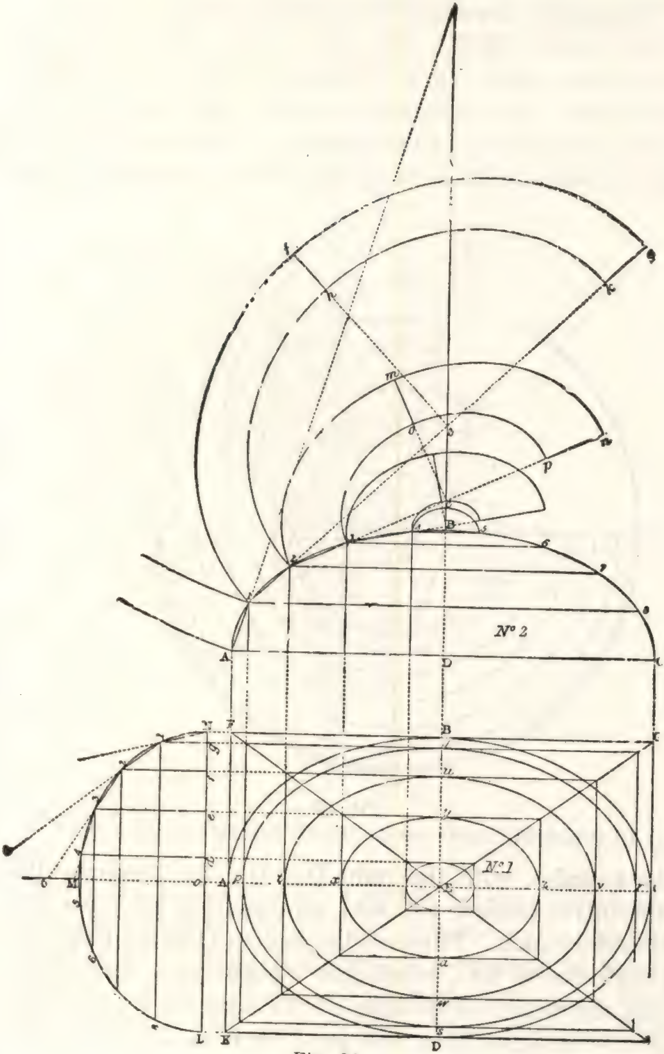


Fig. 91

To find the covering of an annular vault.

Let A C K G E F A (Fig. 92) be the generating section of the vault. On A C describe a semi-circle A B C, and divide its circumference into equal parts, representing the boards of the covering. From the divisions of the semi-circle, b, m, t, &c., from the centre D of

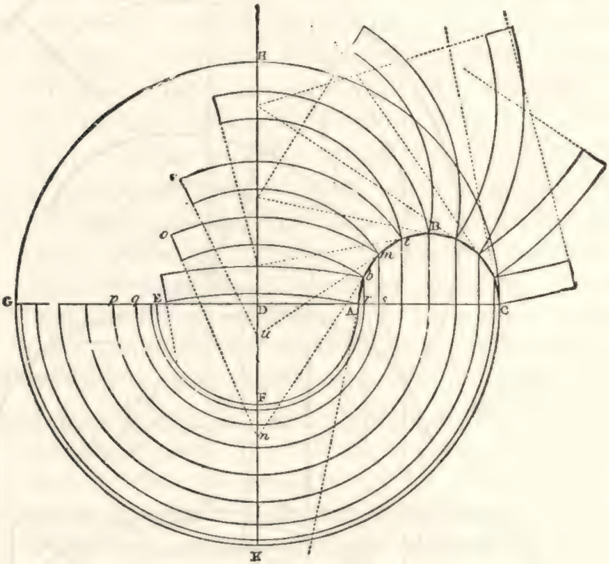


Fig. 92.

the annulus, with the radii D r, D s, &c., describe the concentric circles, s q, &c., representing the covering boards in plan. Through the centre D draw H K perpendicular to G C, indefinitely extending it through K Join the points of division of the semi-circle, A b, b m, m t, by straight lines, and produce them until they cut

the line K H as m b n, t m u, when the points n, u, &c., are the centres from which the curves of the covering boards m o, t v, &c., are described.

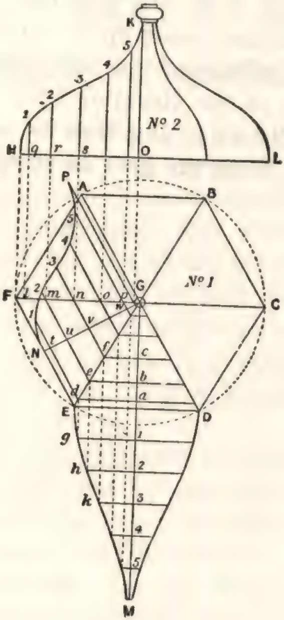


Fig. 93.

To find the covering of an ogee dome, hexagonal in plan.

Let A B C D E F (No. 1, Fig. 93) be the plan of the dome, and H K L (No. 2) the elevation, on the diameter F C. Divide H K into any number of equal parts in 1, 2, 3, 4, 5, k, and through these draw perpendiculars to H L, and produce them to meet F C

(No. 1) in l, mm, n, o, p, G. Through these points draw lines l d, me, n f, &c., parallel to the side F E of the hexagon: bisect the side F E in N, and draw G N, which will be the seat of a section of the dome, at right angles to the side E F. To find this section nothing more is required than to set up on N G from the points t, u, v, &c., the heights of the corresponding ordinates q l, r 2, s 3, &c., of the elevation (No. 2) to draw the ogee curve N 1 2 3 4 5 p, and then to use the divisions in this curve to form the gore or covering of one side E g h k M D.

PART II.

PRACTICAL SOLUTIONS.

Having taken a thorough course in Solid Geometry, the student should be now prepared to solve almost any problem in practical construction, almost as soon as they present themselves. The various problems in construction, however, are so numerous, and in many cases, so intricate, that the student will often be confronted by problems which will require so many applications of the rules he has been taught, in different forms, that without some helping guidance, he will fail to see exactly what to do.

The following examples, with their explanations, are intended to give him the aid necessary to solve many difficult problems, and equip him with the means of still further investigation and sure results.

It is often necessary for the workman to find the exact stretchout or length of a straight line that shall equal the quadrant or a semi-circle.

To accomplish this:—Take A B radius, and A centre; intersect the circle at C; join it and B; draw from D, parallel with C B, cutting at H; then A H will be found equal to curve A D. Fig. 1.

This method is somewhat different to that already given; both, however, are practical.

Fig. 2. To find a straight line which is equal to the circumference of a circle. Draw from the centre, O,

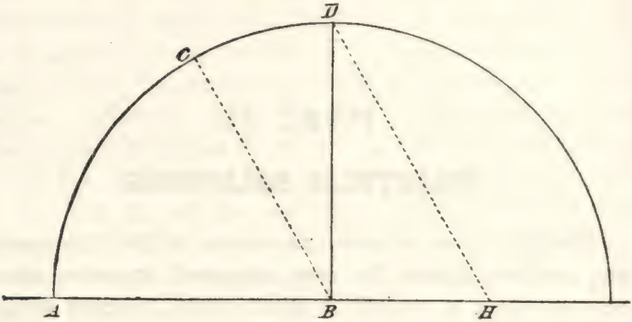


Fig. 1.

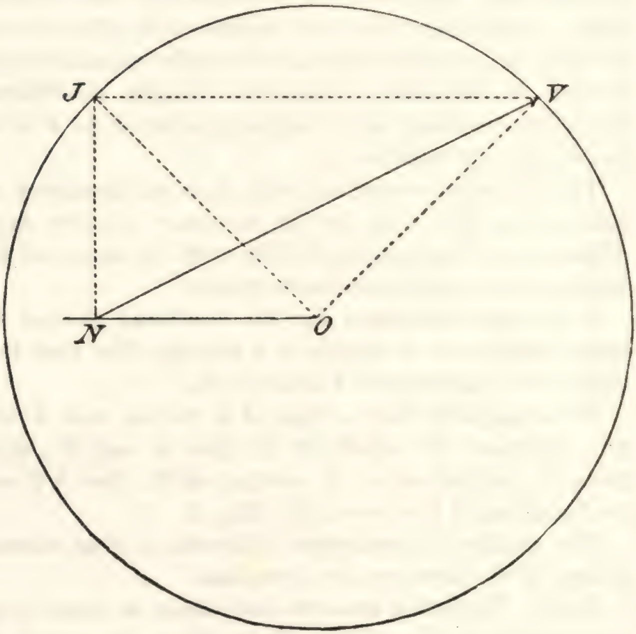


Fig. 2.

any right angle, cutting at J and V; join J V; draw from O parallel with J V; square down from J, cutting at N; joint it and V; then four times N V will be found to equal the circumference.

How to find the mitres for intersecting straight and circular mouldings.

Figure 3 shows the form of an irregular piece of framing or other work, which requires to have mouldings mitre and properly intersect.

The usual way of doing this is to bisect each angle, or to lay two pieces of moulding against the sides of framing, and mark along the edge of each piece, thus making an intersectic or point, so that by drawing through it to the next point, which is the angle of framing, the direction of mitre is obtained. This process, however, is not the quickest and best by any means. The most simple and correct method is to extend the sides A L and P H.

Now suppose we wish to find a mitre from L; take it as centre, and with any radius, as K, draw the circle, cutting at J; join it and K draw from L parallel with J K, and we have tne mitre at once.

Now come to angle on the right; here take H as centre, and with any radius, as E, draw the circle, cutting at F; join it and E; draw from H parallel with E F, and you will find a correct mitre.

The next question is the intersection of straight and circular mouldings.

In the present case an extreme curve is given, in order to show the direction of mitre here, which is simply on the principle of finding a centre, for three points not on a straight line. For example, A B C are

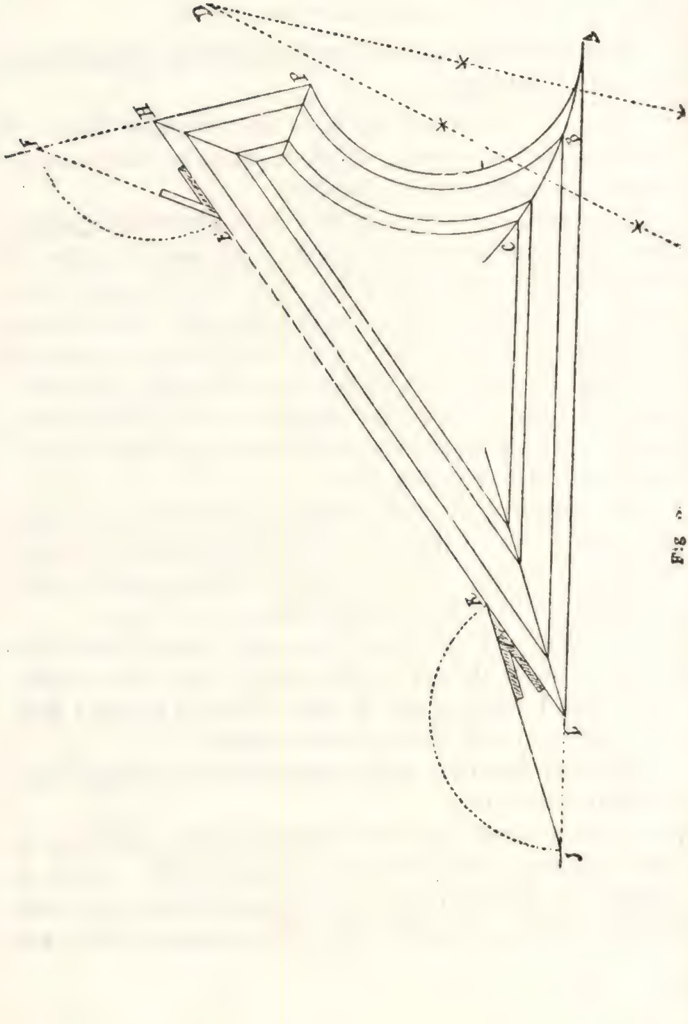


Fig. 2

points; bisect A B and B C; drawn through intersections thus made, and lines meeting in point D give a centre, from which strike the circular mitre as shown.

Here it may be stated that in some cases a straight line for mitres will answer; this means when the curve is a quadrant or less.

Fig. 4 shows the intersections of rake and level mouldings for pediments.

The moulding on the rake, increases in width, and is entirely different from that on the level, yet both mitre, and intersect, the rake moulding being worked to suit the level. If the curves of Fig. 4 are struck from centres as shown, then by the same rule, the rake moulding is also struck from centres.

Take any point in the curve, as C; square up from it, cutting at B; draw from C parallel to S L; join L K, which bisect at N; make E D equal to A B on the right; join L D and D N; bisect L D, also D N; draw through intersections thus made, and the lines meeting in F, give a point from which draw through N; make N J equal H F; then F and J are centres, from which strike the curve, and it will be found to exactly intersect with that of Fig. 4.

Both mouldings here are shown as solid, and of the same thickness. This is done for the purpose of making the drawing more plain and easily understood; but bear in mind that all crown mouldings are generally sprung.

To find the form of a sprung or solid moulding on any rake without the use of either ordinates or centres.

It may not be generally known, that if a level moulding is cut to a mitre, that the extreme parts of mitre,

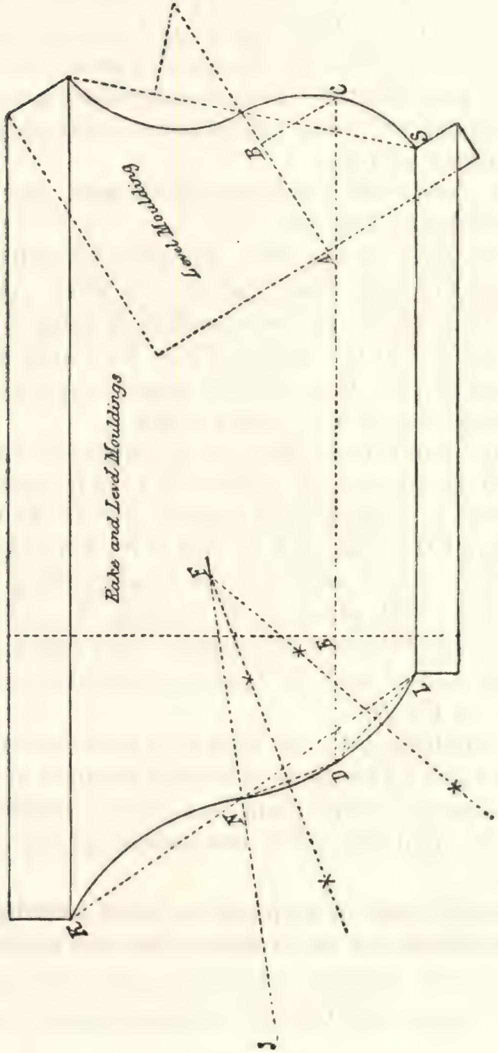


Fig. 4.

when in a certain position, will instantly give the exact form of a rake moulding, and it will intersect, and mitre correctly with that of level moulding. To do this, take the level piece which has been mitred; lay its flat surface on the drawing; make its point P at Fig. 5, stand opposite point P at Fig. 6; keep the outer edge fair with line N L. The piece being in this position, take a marker, hold it plumb against the mitre, and in this way, prick off any number of points as shown, through which trace the curve line, and the result is a correct pattern by which the rake moulding is worked.

A moment's consideration will convince us that this simple method must give the exact form of any rake moulding to intersect with one on the level.

To cut the mitres and dispense with the use of a box, this method will be found quick and off-hand. Take, for example, the back level moulding, and square over on its top edge any line, as that of F N; continue it across the back to H; make H V equal T L above, and from V, square over lower edge H K. Now take bevel 2 from above, and apply it on top edge, as shown; mark F L; then join L V; cut through these lines from the back, and the mitre is complete.

To cut the mitre on the rake moulding, square over any line on its back, as that of H J; continue it across the top and lower edge; take bevel X, shown above Fig. 5, apply it here on top edge, and mark D A; take the same bevel, and apply it on small square at E, and mark E 2.

We now want the plumb cut on lower edge J K, and the same cut on front edge N P, shown at Fig. 6. Take

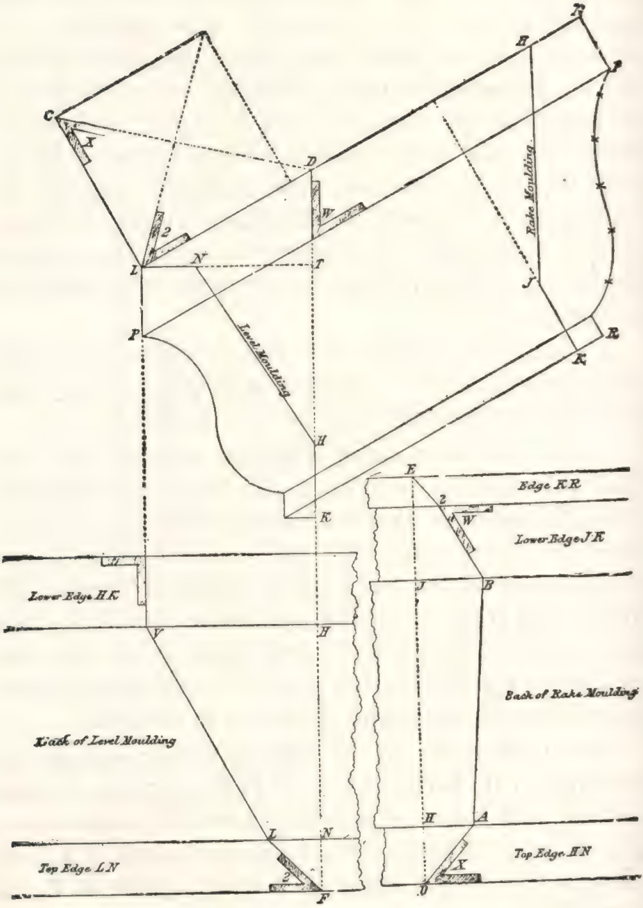

Rake Moulding
Level Moulding
Edge KR
Lower Edge JK
Lower Edge HK
Back of Rake Moulding
Back of Level Moulding
Top Edge LN
Top Edge HN

Fig. 5. Fig. 6.

bevel W above Fig. 5, apply it here and mark 2 B; join B A; this done, apply the same bevel on front edge N P, and mark the plumb cut, it being parallel with that of 2B here, or K J, Fig. 5; now cut through lines on the back, and the mitre is complete.

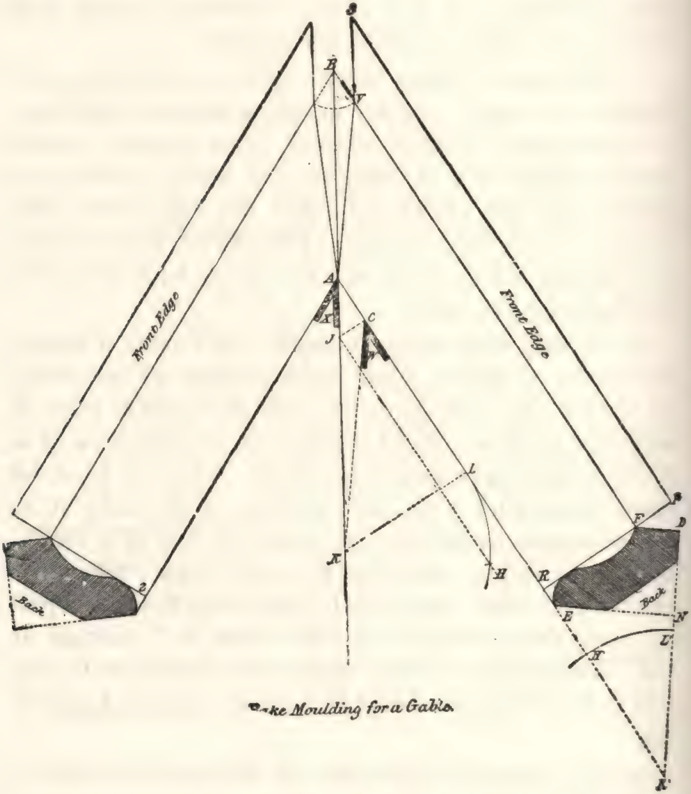
It has already been shown, that we dispense with making or using a box for mitreing sprung mouldings.

In this case, the front edge or upper member, stands parallel with face of wall, so that bevel X being appiled, gives the plumb cut; then the cut on top edge is square with face of wall. This shows, that we have only to find the direction of a cut on the back of moulding to make the mitre.

To do this, take any point as R; draw from it square with rake of gable. Now mark sections of moulding, as shown, its back parallel with R F; draw from D square with E N; extend the rake to cut line from D at K; this done, take any point on the rake, say L; draw from it parallel with R F, cutting at K; take it as centre and L as radius, and draw the arc of a circle; with same radius return to K on the right; take it as centre, and draw the arc L H; make the first arc equal it; then draw from H parallel with L C, cutting at C J; draw from it square with rake, cutting at C, and join C K. This gives bevel W for cut on back of moulding.

A most perfect illustration of this may be had by having the drawing on card-board, and cutting it clear through all the outer lines, including that of the moulding on lines F D N E, making a hinge by a slight cut on line R F; also make a hinge of line R A, by a slight cut on the back, and in like manner make front edge

work on a hinge by a slight cut on line F V. This cut is made on top surface. Perform the same operation



Rake Moulding for a Gable.

Fig. 7.

on the left. All the cuts being made, raise both sides on hinges A R and A 2; push the sections of mouldings on right and left from you; make front edge rest

on F D. Now bring mitres together, and we have a practical illustration of mitreing sprung mouldings on the rake. (See Fig. 7.)

PROJECTION OF SOLIDS.

The following illustrations will be found by the student almost indispensable in the construction of various objects, and they will open the door to many more.

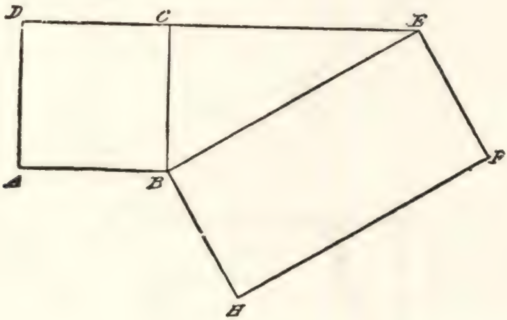


Fig 8.

Fig. 8 shows the projection of a solid. This means the section of anything that is cut by a plane not parallel to its base; or, to put this in a more practical way —take a square bar of wood and cut it in the direction of B E; the section it makes is shown by B E F H; simple as this is, it still gives the idea of what is meant by projection.

Fig. 9 shows the section of a square bar which has been cut by two unequal pitches, say in the direction of bevels J and H; the line C B is called the seat; from it all measurements are taken and transferred to lines that are square with the pitch A B; this pitch may be called a diameter, because it and the ordinate A E are at right angles.

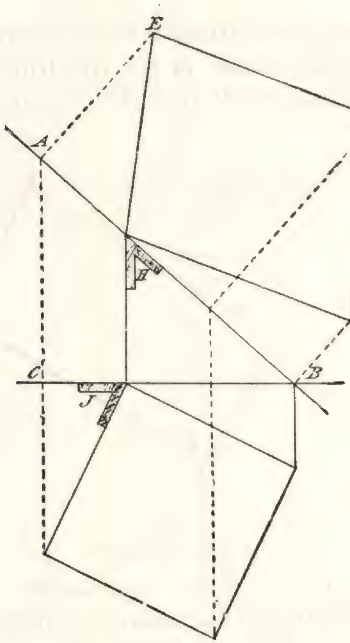


Fig. 9.

Fig. 10 shows the sides of a square bar which may be any length. The bar is to stand perpendicular, and pass through a plank that inclines at A B; the learner

is now required to show on the surface of plank the shape of a mortise that shall exactly fit the bar.

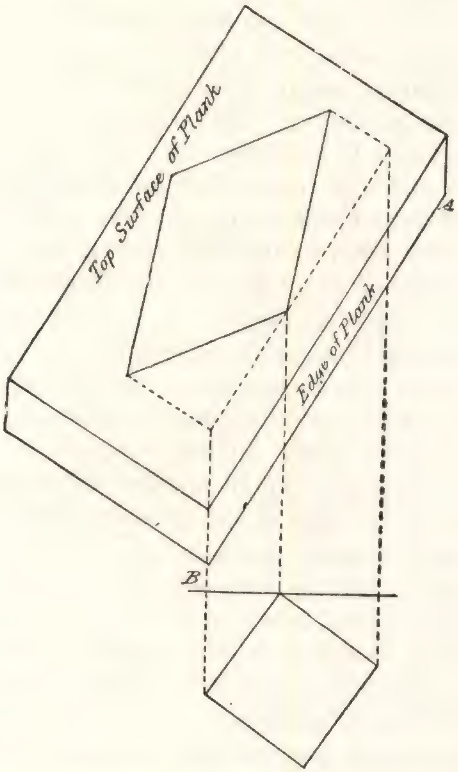


Fig. 10.

To solve this the student is left to exercise his own intelligence.

The problem may be clearly demonstrated by a card-board model; it being cut, and the parts pro-

jected from the flat surface will represent the plank, and show the mortise in it standing directly over the square, Fig. 10.

Fig. 11. It is here required to mark two unequal pitches on two sides of a square bar—then to have a piece of plank or board cut so that it shall exactly fit both pitches on the bar. The inclination of plank may be assumed as A B, and height of both pitches as H A; let E F be the seat from which all measurements are taken, and transferred to lines that are on the surfaces of plank and square with A B; thus giving points to direct in drawing line C D; and D E produced.

Could we apply the bevel J to points C and K, and have plumb lines on the edge of plank, then by cutting through these and those already marked on the surface, the problem would at once be solved, by making both upper and under surface of plank fit the two pitches as required. But in practice this would be inadmissible on account of the great waste of material.

The proper method is to take any point, E, and cut through the plank square with E D, and at C, cut through the plank square with C D; here it will be noticed that line A D on the surface makes a very different pitch to that of A B on the edge of plank, and that C D differs from both.

To understand these points thoroughly is the true secret of the nicest element in the joiner's art—hand railing. It being clear that two bevels are required one for each pitch—proceed to find them. Make N L equal one side of the square. Take N as center, and strike an arc touching the line E D; with same radius, and L centre, make the intersection in S; join it at L,

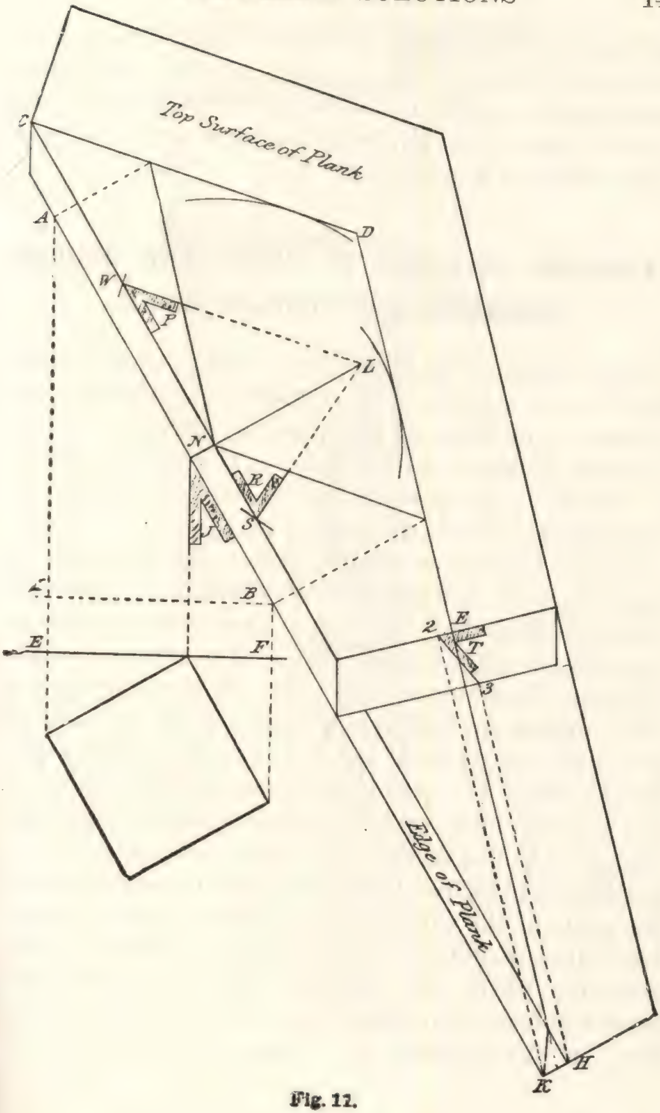


Fig. 11.

which gives bevel R for joint at E. Again take N as centre, and strike an arc touching line D C; with same radius, and L centre, make the intersection in W; join it and L, which gives bevel P for joint at C; the cuts being made by these bevels.

PANELLED CEILINGS IN WOOD AND STUCCO BRACKETS, AND SIMILAR WORK.

It is no part of the duty of this work to show designs for wooden ceilings, but in order to illustrate the method or methods, of constructing a wooden ceiling I deem it proper to show a design in this style the better to convey to the student the reason for the various steps taken to reach the desired result.

Fig. 12 shows a section of a roof and the mode of constructing a bracketed ceiling under it, but with slight modification the same arrangement can be adopted for ceilings under floors. The rafters A A are 18 inches from centre to centre. On these, straps a a, 3X1½ inches, are nailed at 16 inches apart, and similar straps a a, 1¼X1 inch, are nailed to the ceiling joists. To the straps are nailed the brackets b b b, shaped to the general lines of the intended ceiling, and also placed 14 inches apart. The laths are nailed to the brackets for the moulded parts, and to straps for the flat parts of the ceiling. The brackets and the straps for ceiling should not be more than one inch in thickness, for where the brackets and straps occur the plaster cannot be pressed between the laths to form a key. If the brackets and straps are made thicker,

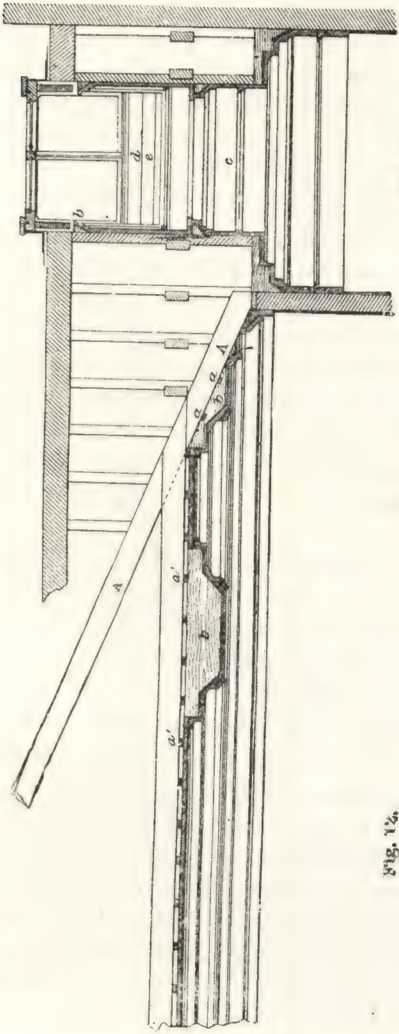


Fig. 15.

Fig. 12.

parts of the ceiling are apt to be weak and irregular. The lathing should be well bonded and have no end joints longer than twelve inches on the ceiling, and twenty-four inches on the walls and partitions. No joints of laths should be overlapped, as the plaster would thereby be made thinner at a part where it forms a no key, and would thus be liable to crack from the vibration of roof, floor or other causes.

Fig. 13 is a section on a larger scale at right angles to that shown in Fig. 12. Here the ceiling bracket b is shown affixed by hooks to the wall, and to the ceiling-joists by the strap a a. The ceiling having been plastered, and the mouldings of the cornice run on the lathed brackets prepared to receive them, the plaster enrichments marked c d e f g are then applied. No. 3 on Fig. 2 shows a curtain-box in section with its curtain-rod.

Fig. 14 is a section through a window-head, meeting-rails and sill of a window. The safe lintel is placed about 10 inches above the daylight of the window, for the purpose of allowing venetian blinds to be drawn up clear of the window, and leave the light unobstructed. The framing of the window is carried up to the lintel, and between it and the upper sash a panel is set in, and the blinds hang in front of it.

Fig. 15 is a cross vertical section, and Fig. 16 a plan, looking up, of a skylight on the ridge of a roof, suitable for a staircase or corridor. The design can be adopted to suit various widths. The skylight is bracketed for plaster finishings, in the same manner as the ceiling already described. The framing and mouldings at b are carried down the side of the light at the same slope

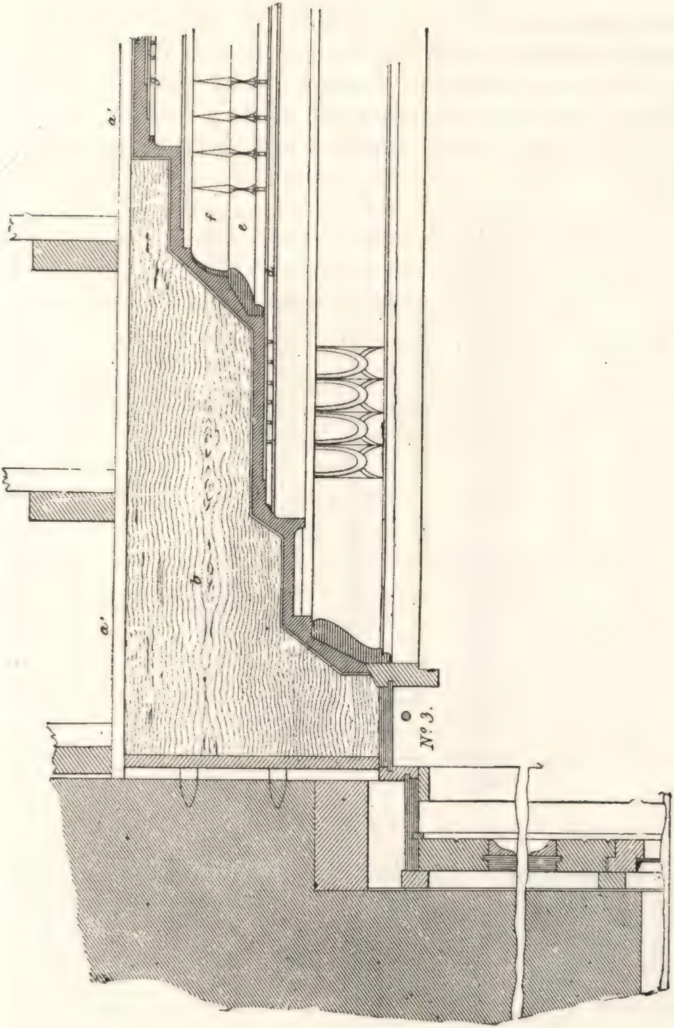


Fig. 13.

Fig. 14.

as the sash, till they butt against the sill and bridle d and e, forming a triangular panel having for its base the cornice c, which is carried round the aperture horizontally, and finishing flush with the ceiling, permits the cornice on the corridor to be continued with-

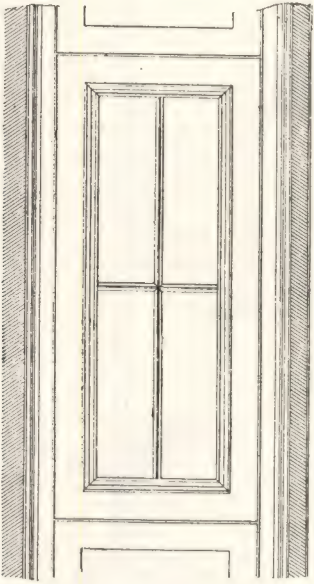


Fig. 16.

out interruption. Observe in Fig. 16 the lower cornice finishes the walls, and the upper mouldings 0 marked c in Fig. 15 are carried round the well of the skylight.

Fig. 17 shows a plan of a panelled ceiling. The lower members or bed mouldings are carried round the walls of the room, and tend to build together, and give an

appearance of support to the several parts of the ceiling. The best way of making panelled ceilings is to cover the floor with boarding, and lay down the lines of the ceiling on the temporary floor thus formed. Then build and lath the ceiling on these lines. When it is completed it will be quite firm, and can be cut into sections suitable for being lifted up and attached to the joisting. The same lines will serve as guides for the plasterer setting the moulds for running the cornices and for preparing the circular ornament.

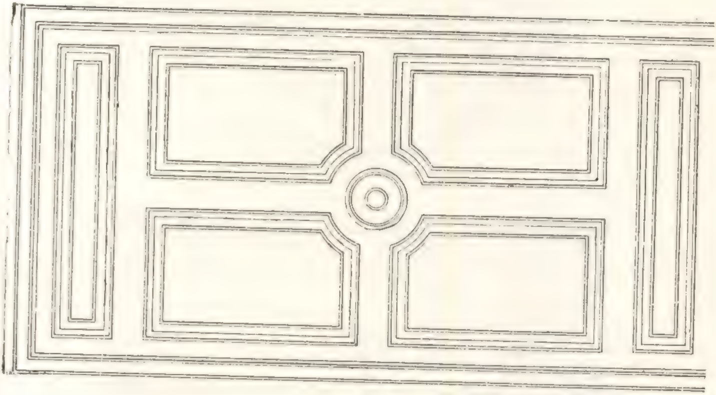


Fig. 17.

Fig. 18 shows in plan and section a centre suited for this ceiling. By fixing the central portion of it one inch from the surface of the finished ceiling and connecting it by small plaster blocks placed about one inch apart, it forms an excellent ventilator. A zinc tube can be led from this centre into a vent, and an

air tight valve put on the tube to prevent a down draft when the vent is not in use. F is an iron rod fixed to

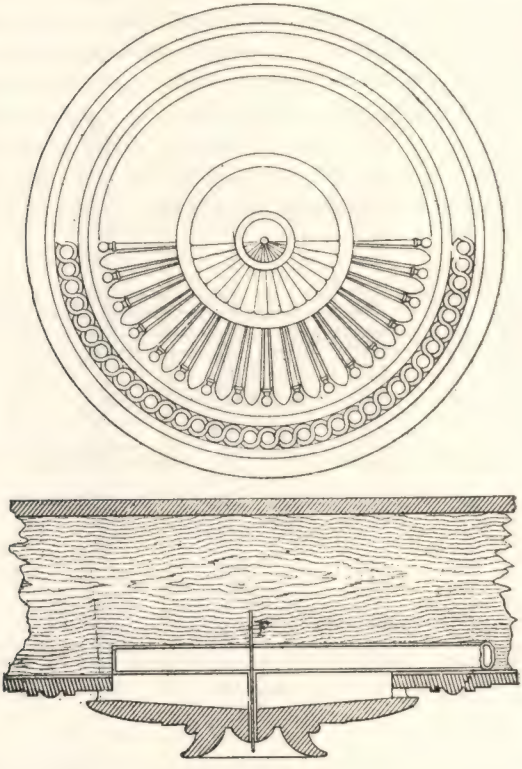


Fig. 18.

a strut or dwang between the joists for the purpose of securing a gas pendant or electrolier.

Let C A B (Fig. 19) be the elevation or the bracket of a core, to find the angle-bracket.

First, when it is a mitre-bracket in an interior angle, the angle being 45°: divide the curve C B into any

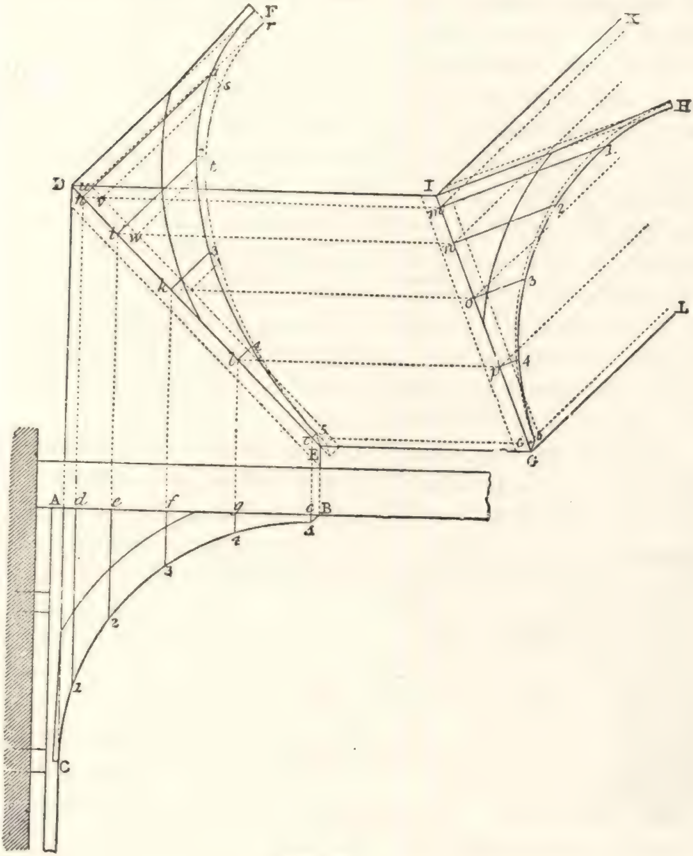


Fig. 19.

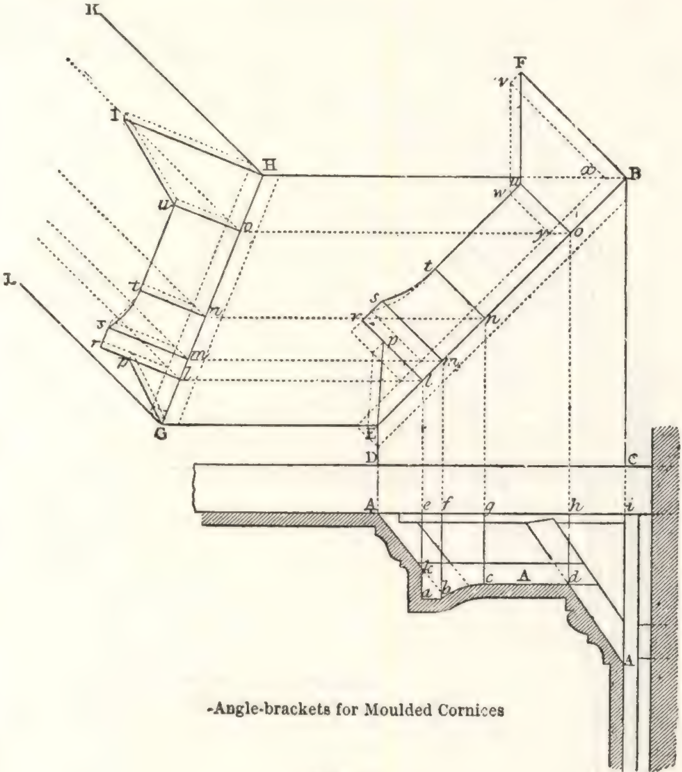
number of equal parts 1 2 3 4 5, and draw through the divisions the lines 1d, 2e, 3f, 4g, 5c, perpendicular

A B, and cutting it in d e f g c; and produce them to meet the line D E, representing the centre of the seat of the angle-bracket: and from the points of intersection h i k l c draw lines h 1, i 2, k 3, l 4, at right angles to D E, and make them equal—h 1 to d 1, i 2 to e 2, &c.; and through F 1 2 3 4 5 draw the curve of the edge on the bracket. The dotted lines on each side of D E on the plan show the thickness of the bracket, and the dotted lines u r, v s w t, show the manner of finding the bevel of the face. In the same figure is shown the manner of finding the bracket for an obtuse exterior angle. Let D I K be the exterior angle: bisect it by the line I G, which will represent the seat of the centre of the bracket. The lines I H, m 1, n 2, o 3, p 4, c 5, are drawn perpendicular to I G, and their lengths are found as in the former case.

To find the angle-bracket of a cornice for interior and exterior, otherwise reentrant and salient, angles.

Let A A A (Fig. 20) be the elevation of the cornice-bracket, E B the seat of the mitre-bracket of the interior angle, and H G that of the mitre-bracket of the exterior angle. From the points A k a b c d A, or wherever a change in the form of the contour of the bracket occurs, draw lines perpendicular to A i or D C, cutting A i in e f g h i and cutting the line E B in E l m n o B. Draw the lines E G, G L B H, and H K, representing the plan of the bracketing, and the parallel lines from the intersection l m n o, as shown dotted in the engraving; then make B F and H I perpendicular to E B and G H respectively, and each equal to i A, o u to h d, n t to g c, m s to f b, l r to e a, l p to e k, and join the points so found to give the con-

tours of the brackets required. The bevels of the face are found as shown by the dotted lines x v y w, &c.



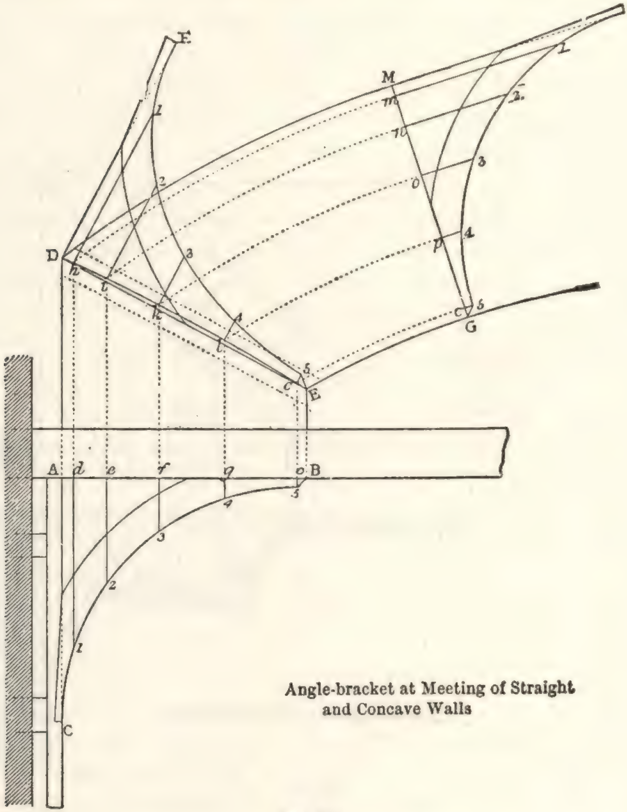
-Angle-brackets for Moulded Cornices

Fig. 20.

To find the angle-bracket at the meeting of a concave wall with a straight wall.

Let A D E B (Fig. 21) be the plan of the bracketing on the straight wall, and D M G E the plan on the cir-

cular wall, C A B the elevation on the straight wall, and G M H on the circular wall. Divide the curves

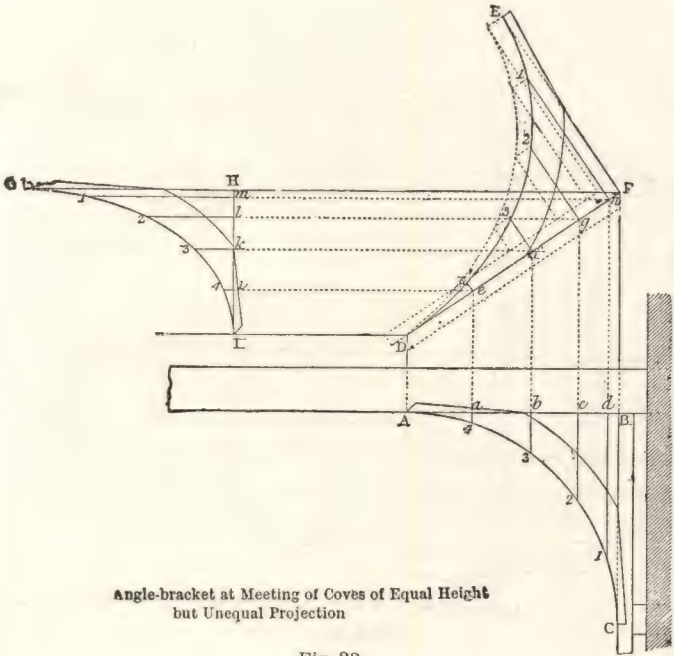


Angle-bracket at Meeting of Straight and Concave Walls

Fig. 21.

C B, G H into the same number of equal parts; through the divisions of C B draw the lines C D, 1 d h, 2 e i, &c., perpendicular to A B and through those of G H draw

the parellel lines, part straight and part curved 1 m h, 2 n i, 3 o k, &c. Then through the intersections h i k l of the straight end curved lines draw the curve D E, which will give the line from which to measure the ordinates h 1, i 2, k 3, &c.

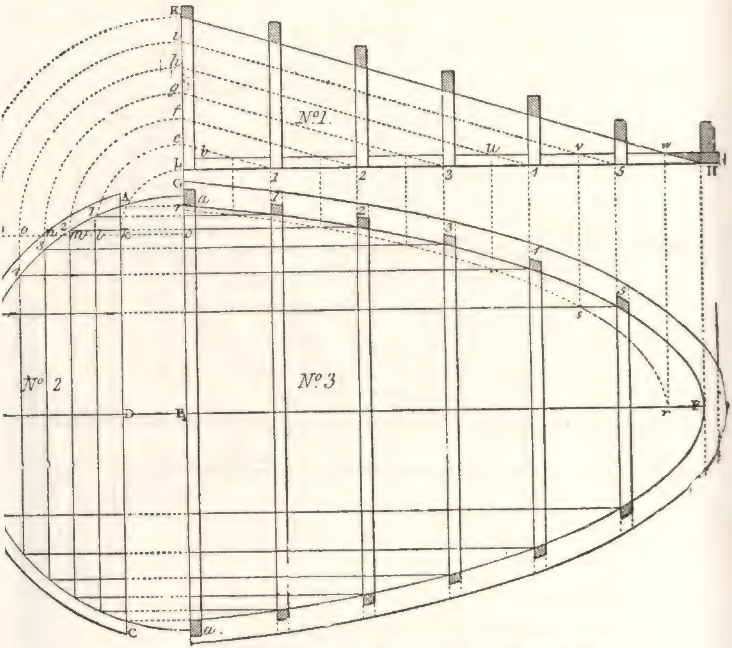


Angle-bracket at Meeting of Coves of Equal Height but Unequal Projection

Fig. 22.

Fig. 22 shows the method of finding the angle-bracket at the meeting of coves of equal height but unequal projection. The height C B is equal to G H, but the projection B A is greater than H I.

Fig. 23, Nos. 1, 2, 3, shows the curb and ribs of a circular opening (C B A, No. 2), cutting in on a sloping ceiling. No. 1 is a section through the centre B D, No. 2 and E F I, No. 3. The height L K is divided into

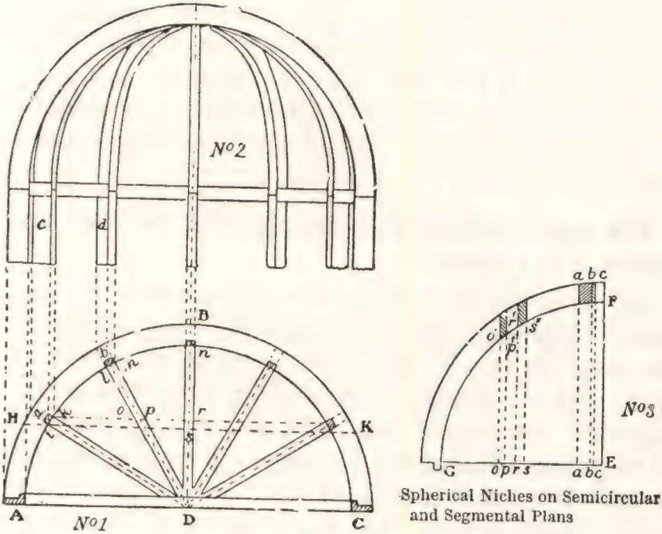


Curb and Ribs of Circular Arch Cutting into Sloping Ceiling

Fig. 23.

equal parts in e, f, g, h, i, and the same heights are transferred to the main rib in No. 2 at A, 1, 2, 3, 4, 5, B. Through the points A, 1, 2, 3, 4, 5, in No. 2 lines are drawn parallel to the axis B E I; and through the points e, f, g, h, i, in No. 1 lines are drawn parallel to

the slope K H. The places of the ribs 1, 2, 3, 4, 5, in the latter, and their site on the plan. No. 3, and also the curve of the curb, are found by intersecting lines in the manner with which the student is already acquainted.



Spherical Niches on Semicircular and Segmental Plans

Fig. 24.

ON NICHES.

To describe a spherical niche on a semi-circular plan. The construction of this (Fig. 24) is precisely like that of a spherical dome. The ribs stand in planes, which would pass through the axis if produced. They are all of similar curvature. No. 2 shows an elevation

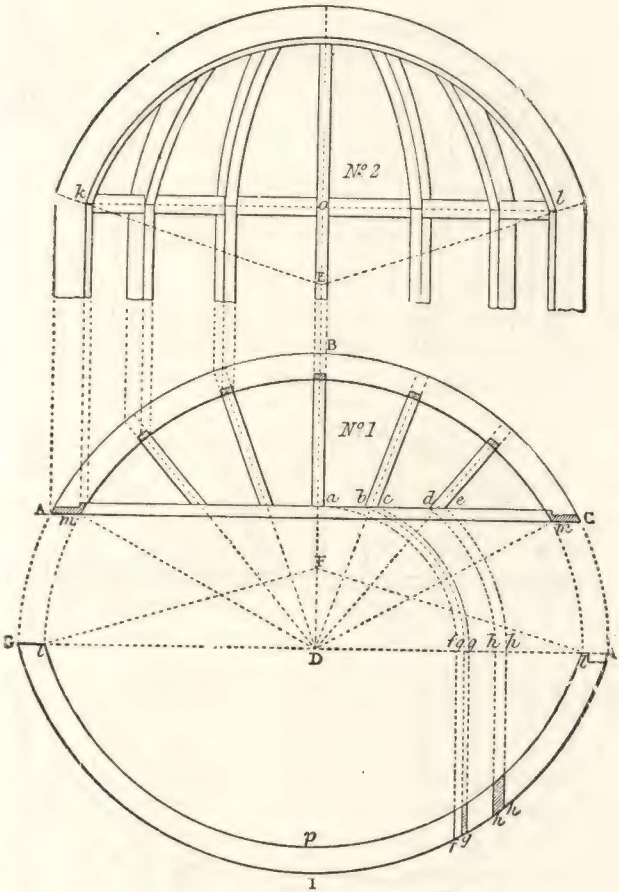
of the niche, and No. 3 the bevelling of the ribs a, b, against the front rib at D on the plan; a b is the bevel of a, and b c of b.

Let H B K (Fig. 24) be the plan. It is obvious that the ribs m p, nr, will be parts of the quadrant G F (No. 3). Transfer the lengths lo, m p, n r, and r s to the line G E, as shown at o p r s, and raise perpendiculars from these points to the quadrant; G p is the rib m p, and o p is the bevel; G r is the rib nr, and r s is the section of the front rib at the crown; the vertical projection of the upper arris of this rib will be a semicircle with radius s s or s H.

The niche of which both the plan and elevation are segments of a circle.

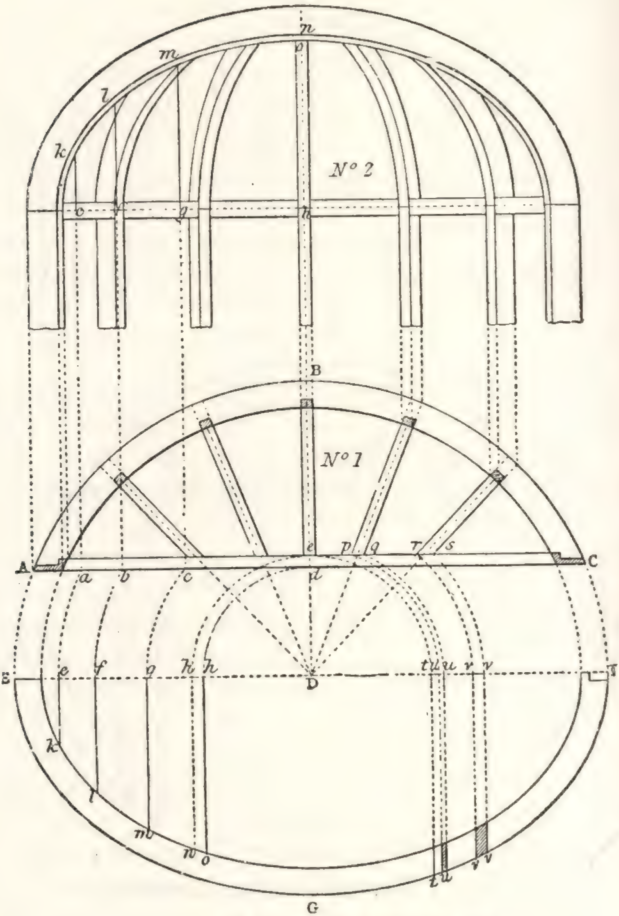
No. 25 is the elevation of the niche, being the segment of a circle whose centre is at E. No. 1, A B C, is the plan, which is a segment of a circle whose centre is D. Having drawn on the plan as many ribs as are required, radiating to centre D, and cutting the plan of the front rib in a, b c, d e; then through the centre D draw the line G H parallel to A C; and from D describe the curves m l, A G, C H, cutting the line G H· and make D F equal to E O, No. 2. From F as a centre describe the curves l p l and G I H for the depth of the ribs; and this is the true curve for all the back ribs.

To find the lengths and bevel of the ribs:—From the centre D describe the quadrant and arcs a f, b g, c g, d h, &c., and draw f f, g g, h h perpendicular to D H, cutting the curve l p l, and the lines of intersection will give the lengths and bevels of the several ribs.



-Segmental Niche on Segmental Plan

Fig. 25.



Elliptical Niche on Segmental Plan

Fig. 26.

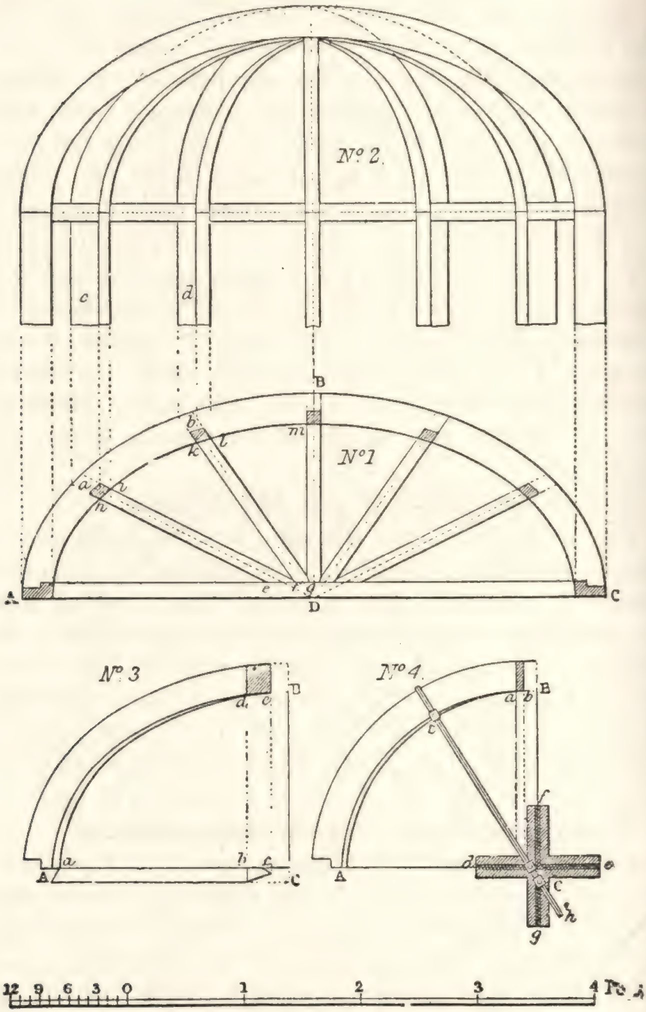
Let D in the plan (No. 1, Fig. 26) be the centre of the segment. Through D draw E F parallel to A C, and continue the curve of the segment to E F. Then to find the curve of the back ribs:—From k l m n, any points in the curve of the front rib (No. 2) let fall perpendicular to the line A B, cutting it in a b c d. Then from D as a centre describe the curves a e, b f, c g, e h, d h, and from the points where they meet the line E F draw the perpendiculars e k, f l, g m, h n, h o, and set up on e k the height ek of the elevation and the corresponding heights on their other ordinates, when k l m n o will be the points through which the curve of the radial ribs may be traced. The manner of finding the lengths and bevels of the ribs is shown at t u u v v.

A niche semi-elliptic in plan and elevation.

Let No. 1, Fig. 27, be the plan, and No. 2 the elevation of the niche. The ribs in this case radiate from the centre D, and with the exception of m g (which will be the quadrant of a circle) they are all portions of ellipses, and may be drawn by the trammel, as shown in No. 4, which gives the true curve of the rib marked d in No. 2 and b D in No. 1. The rib c, in the elevation, is seen at a D in No. 1; the bevel of the end h i is seen at A a in No. 3, and that of the end e f at b c.

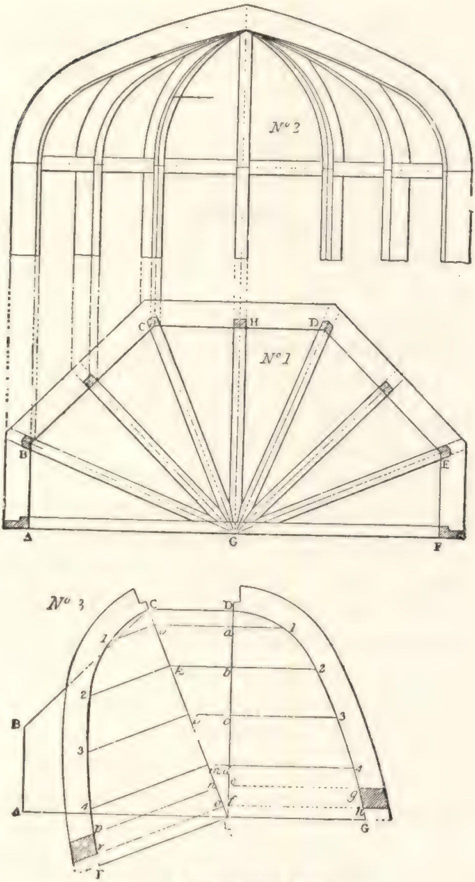
To draw the ribs of a regular octagonal niche.

Fig. 28.—Let No. 1 be the plan, and No. 2 the elevation of the niche. It is obvious that the curve of the centre rib H G will be the same as that of either half of the front rib A G, F G. In No. 3, therefore, draw A B C D E, the half-plan of the niche, equal to A B C H G, No. 1, and make D G E equal to half the



Elliptical Niche on Elliptical Plan

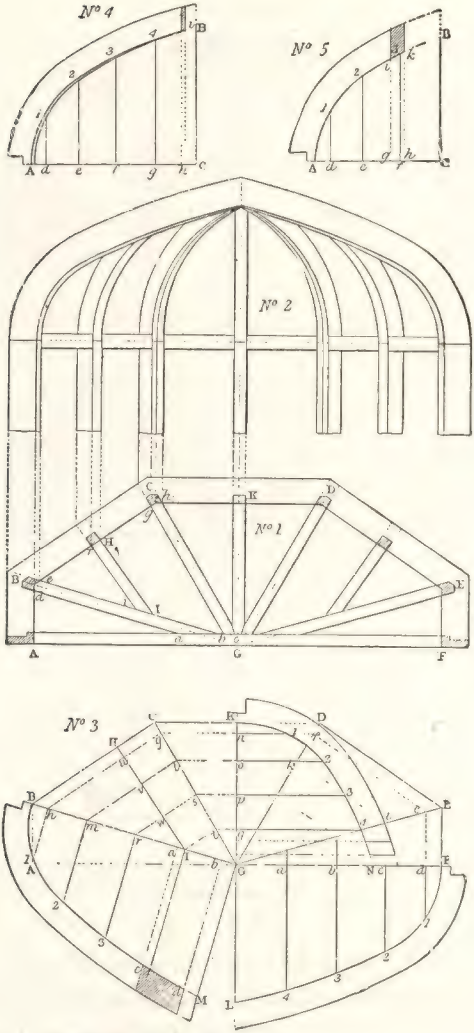
Fig. 27.



Regular Octagonal Niche

Fig. 28.

front rib. Divide D G into any number of parts 1 2 3 4, &c., and through the points of division draw lines parallel to A G, meeting the seat of the centre of the angle



Irregular Octagonal Niche

Fig. 29.

rib C E in i k l m n o. On these points raise indefinite perpendiculars, and set up on them the heights a 1 in i 1, b 2 in k 2, and so on. The shaded parts show the bevel at the meeting of the ribs at G in No. 1.

To draw the ribs of an irregular octagonal niche.

Fig. 29.—Let No. 1 be the plan, and No. 2 the elevation of the niche. Draw the outline of the plan of the niche at A B C D E F (No. 3), and draw the centre lines of the seats of the ribs B G, H I, &c.; draw also G L F equal to the half of the front rib, as given in the elevation No. 2, and divide it into any number of parts 1 2 3 4. Through the points of division draw dl, c 2, b 3, a 4, perpendicular to G F, and produced to the seat of the first angle rib G E. Through the points of intersection draw lines parallel to the side E D of the niche meeting the second angle rib D G; through the points of intersection again draw parallels to D C, and so on. The curve of the centre rib is found by setting up from n o p q G the heights d 1, c 2, &c., on the parallel lines which are perpendicular to K G. The curve of the rib B G or E G is found by dra ving through the points of intersection of the parallels perpendiculars to the seat of the rib, and setting upon them, at h m r I G, the heights d1, c2, &c. No. 4 shows the rib C G, and No. 5 the intermediate rib H I.

DOUBLE CURVATURE WORK.

To Obtain to Soffit Mould for marking the veneer (see Fig. 35), divide the elevation of lower edge of the head (Fig. 30) into a number of equal parts, as A, B, C, D, E S, and drop projectors from these points into

the plan cutting the chord line A″ S″ in A″, B″, C″, D″, E″, S″. Draw the line s′ s′, Fig. 35, equal in length to the stretch out of the soffit in the elevation (the length of a curved line is transferred to a straight one by taking a series of small steps around it with the compasses, and repeating a like number of the straight line), and transfer the points A B C, &c., as they occur thereon, repeating them on each side of the centre line. Erect perpendiculars at the points, and make each of these lines equal in length to its cordespondingly marked line in the plan, as A′ a′ a′ Fig. 35, equal to A″ a a Fig. 32, these letters referring respectively to the chord line and the inside and outside edges of the head. Draw the curves through the points so found. As will be seen by reference to Fig. 35, the mould is wider at the springing than at the crown; this is in consequence of the pulley stiles being parallel. If they were radial their width would be the same as the width of the head at the crown, and the head would be parallel; the gradual increase in width from the crown to the springing is also apparent in the sash-head and the beads, as indicated by the line O O, Fig. 35, which is the inside of the sash-head, and the outside of the parting head; this variation in width renders it impossible to gauge to a thickness from the face or the groove in the head from its edges.

To Form the Head. Having prepared the cylinder (Fig. 33) to the correct size, prepare a number of staves to the required section, which may be obtained by drawing one or two full size on the elevation, as shown to the right in Fig. 36. The staves should be dry straight-grained yellow deal, free from knots and

Fig. 30.

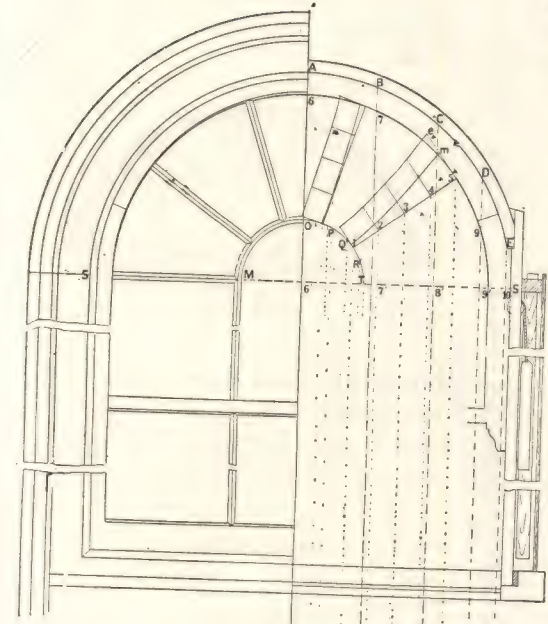


Fig. 31.

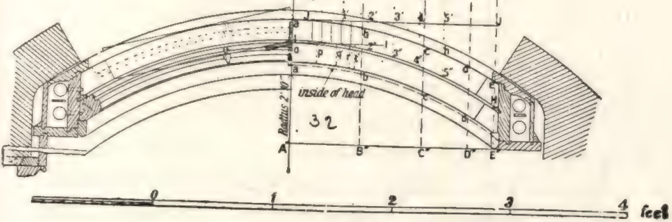


Fig. 32.

sap, and not be so wide that they require hollowing to fit. If the veneer is pine, it will probably bend dry, but hardwood will require softening with hot water. One end

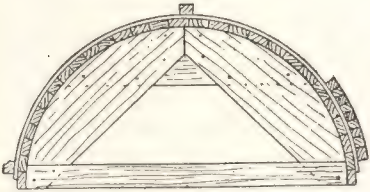


Fig. 33.

should be fixed as shown in Fig. 34, by screwing down a stave across it. Then the other end is bent gently over until the crown is reached,

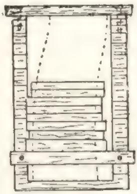


Fig. 34.

when another stave is screwed on, and the bending continued until the veneer is well down all round, and a third stave secures it until it is thoroughly dry. when the re-

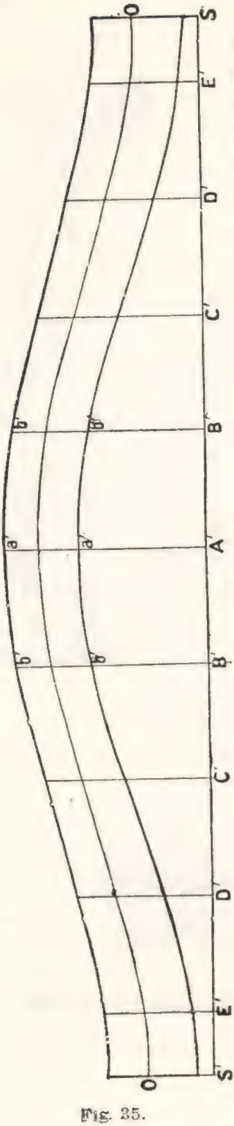


Fig. 35.

mainder may be glued on. It is as well to interpose a sheet of paper between the cylinder and the veneer, in case any glue should run under, which would then adhere to the paper instead of the veneer. The head should not be worked for at least twelve hours after glueing. If a band saw is at hand, the back should be roughly cleaned off and the mould bent round it, the shape marked, and the edges can then be cut vertically with the saw, by sliding it over the cylinder sufficiently

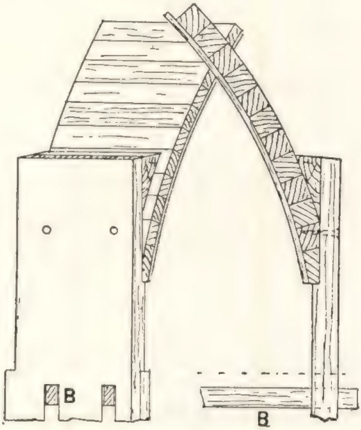


Fig. 36.

for the saw to pass. When cut by hand, the mould is applied inside and the cut is made square to the face, the proper bevel being obtained with the spokeshave, and found by standing the head over its plan and trying a set square against it. When fitting the head to the pulley stiles the correctness of the joints is tested by cutting a board to the same sweep as the sill, with

tenons at each end, and inserting it in the mortises for the pulleys, as shown at B, Fig. 36. A straight-edge applied to this and the sill will at once show if the head is in the correct position, and if the edges are vertical as they should be.

To Obtain a Developed Face Mould. Make the line i h, Fig. 37, equal to the stretch out of the plan of the face of sash-heads, viz., I H, Fig. 32. Transfer the divisions as they occur, and erect perpendiculars thereon.

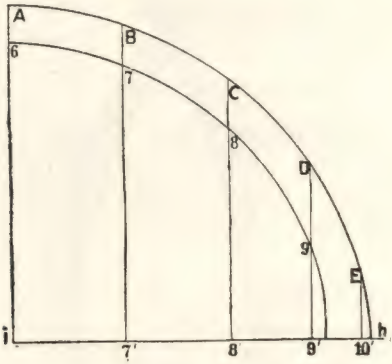


Fig. 37.

Make these equal in height to the corresponding ordinates over the springing line in the elevation, and draw the curves through the points so found. The groove for the parting bead can be marked by running a ⅜ in. piece around the inside of the sash-head, this bead being generally put in parallel. It is sometimes omitted altogether, the side beads being carried up until they die off on the head.

To Find the Mould for the Cot Bar. Divide its centre line in the elevation into equal parts, as O, P, Q, R, T. Drop projectors from these into the plan, cutting the chord line l l in o, p, q, r, t. These lines should be on the plan of the top sash, but are produced across the lower to avoid confusion with the projectors from the other bars. Set out the stretch out of the cot bar

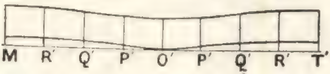


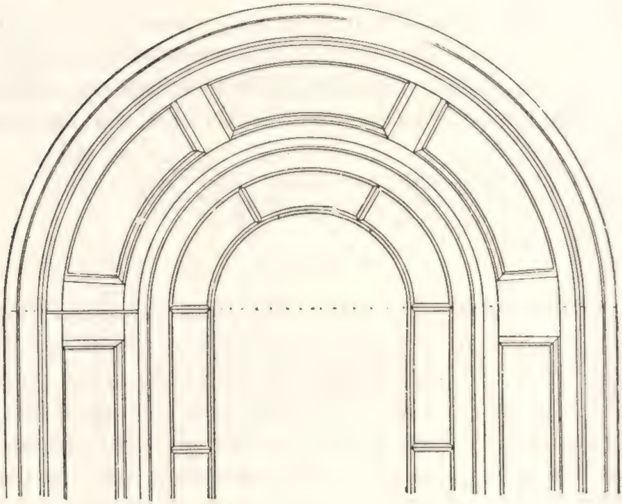
Fig. 38.

on the line M′ O′ T′, Fig. 38, and erect perpendiculars at the points of division, and make them equal in length to the correspondingly marked lines in the plan. The cot bar is cut out in one piece long enough to form the two upright sides as well as the arch. The straight parts are worked nearly to the springing, and the bar which is got out wider in the centre is then steamed and bent around a drum, and afterwards cut to the mould (Fig. 38) and then rebated and moulded. The arched bar should not be mortised for the radial bars, but the latter scribed over it and screwed through from inside.

To Find the Mould for the Radial Bars. Divide the centre line of the bar into equal parts, as 1, 2, 3, 4, 5, Fig. 30, and project the points into the plan, cutting the chord line J J in 1′, 2′, 3′, 4′, 5′. Erect perpendiculars upon the centre line from the points of division, and make them equal in length to the distance of the corresponding points in the plan from the chord line, and draw the curve through the points so obtained.

The other bar is treated in the same manner, the projectors being marked with full lines in the plan.

Fig. 39.



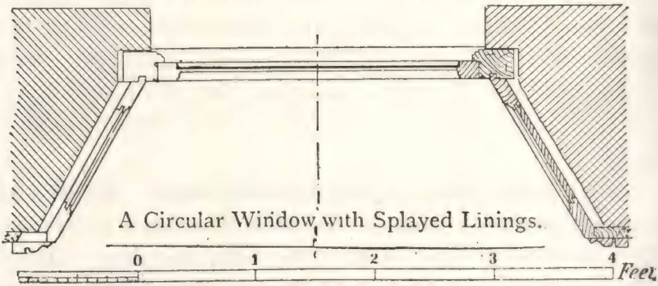


Fig. 40.

The soft moulds for the head linings are obtained in similar manner to those for the head mould, the width being gauged from the head itself

A Frame Splayed Lining with Circular Soffit as shown in part elevation in Fig. 39, plan Fig. 40, and section Fig. 41. The soffit stiles are worked in the solid

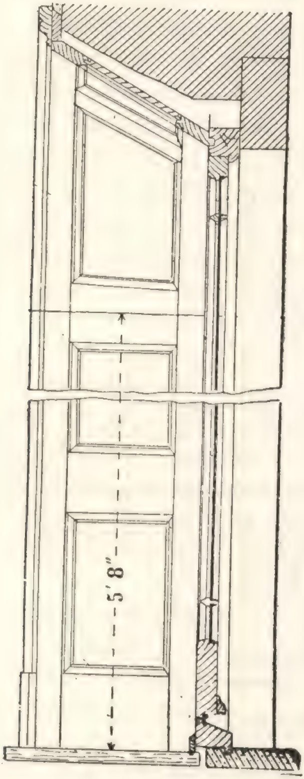
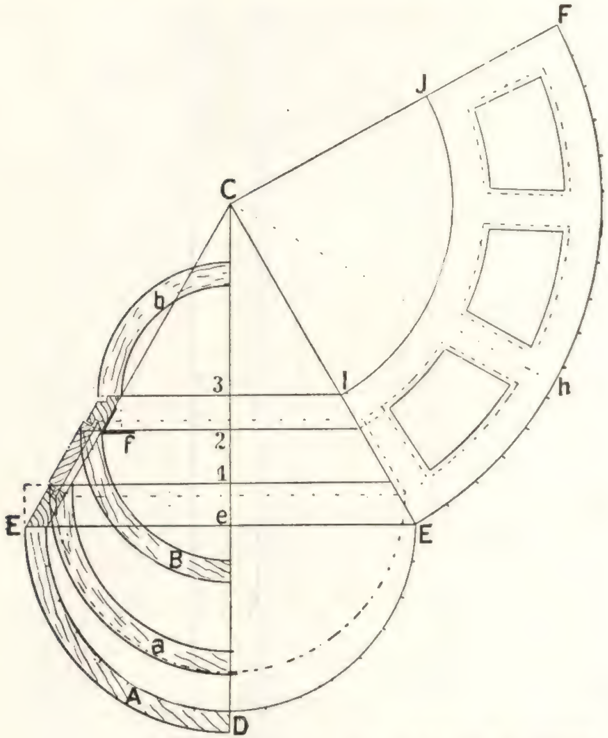


Fig. 41.

in two pieces joined at the crown and springings. The rails are worked with parallel edges, their centre lines radiating from the centre of the elevation. Edge

moulds only are required for the stiles, and a developed mould for the panels. The method of obtaining these has been shown on a separate diagram, Fig. 42.



Method of Obtaining Moulds for Circular Splayed Linings.

Fig. 42.

To Obtain the Face Moulds for the Soffit Stiles. Draw the line E E, Fig. 42, and produce the faces of

the jambs until they meet in point C. From C draw the line C D perpendicularly to E E. This line will contain the centres of the various moulds, which are located by producing the plans of the edges of the stile across it e, 1, 2, 3 being the respective centres, and the inside and outside faces of the jambs affording the necessary radii for describing the arcs A a and B b.

To Apply the Moulds. Prepare the stuff equal in thickness to the distance between the lines e 1 and 2 3, Fig. 42. Apply the mould A to the face of the pieces intended for the front stile, and cut the ends to the mould, and square from the face. Set a bevel as at F, Fig. 42, and apply it on the squared ends, working from the lines on the face, and apply the mould a at the back, keeping its ends coincident with the joints, and at the points where the bevel lines intersect the face. The piece can then be cut and worked to these lines, and the inside edge squared from the face. The outside edge is at the correct bevel, and only requires squaring slightly on the back to form a seat for the grounds. The inside stile is marked and prepared similarly.

The Development of the Conical Surface of the Soffit is shown on the right hand of the diagram, Fig. 42, and is given to explain the method of obtaining the shape of the veneer, but it is not actually required in the present construction, as the panel being necessarily constructed on a cylinder, its true shape is defined thereon, and its size is readily obtained by marking direct from the soffit framing when the latter is put together. Let the semi-circle E D E, Fig. 42, represent a base of the semi-cone, and the triangle E C E its ver-

tical section. From the apex C, with the length of one of its sides as radius, described the arc E F, which make equal in length to the semi-circle E D E by stepping lengths as previously described. Join F to C, and E C F is the covering of the semi-cone. The shape of the frustum, or portion cut off by the section line of the linings, is found by projecting the inner edge of the lining upon the side C E, and drawing the con-

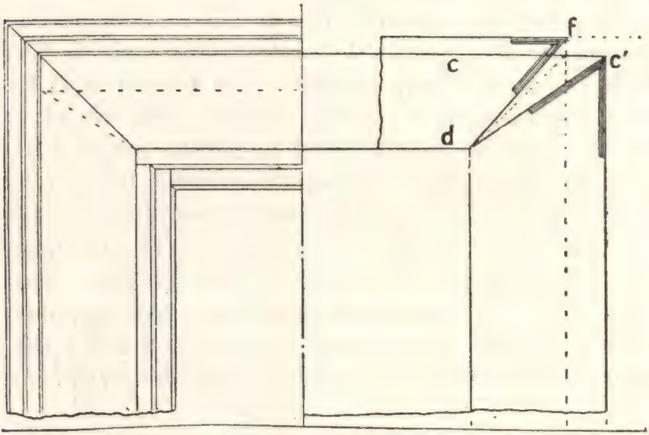


Fig. 43.

centric arc I J; then E I J E represents the covering of the frustum. Any portion of this, the panels for instance, is found in the same way. To draw the rails, divide their centre lines equally on the perimeter, and draw lines from the divisions to the centre as H C; make the edges parallel with these lines.

A Window With a Splayed Soffit and Splayed Jambs is shown in part elevation, Fig. 43, plan Fig. 44; and

section Fig. 45. The linings are grooved and tongued together, as shown in the enlarged section, Fig. 46. To obtain the correct bevel required for the shoulder of the jamb and the groove in the soffit, the lining must

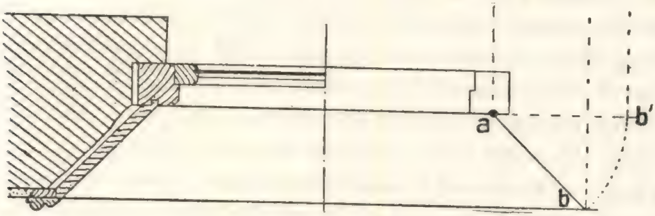


Fig. 44.

be revolved upon one of its edges until it is parallel with the front, when its real shape can be seen. This operation is shown in the diagram on the right-hand

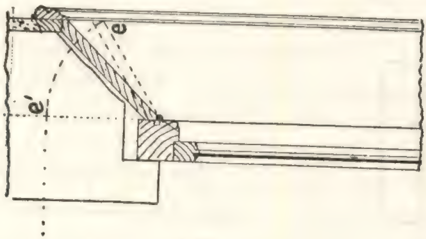


Fig. 45.

half of the plan and elevation. Draw the line a b, representing the face of the jamb in plan, at the desired angle. Project the edges into the elevation, and intersect them by lines c d, projected from the top and bottom edges of the soffit in section. This will give the projection of the linings in elevation. Then from point

a as centre, and the width of the lining a b as radius, describe the arc b b′, bringing the edge b into the same plane as the edge a. Project point b′ into the elevation, cutting the top edge of the soffit produced in c′. Draw a line from c′ to d, and the contained angle is the bevel for the top of the jamb. When the soffit is splayed at the same angle as the jambs, the same bevel will answer for both; but when the angle is different, as shown by the dotted lines at e, Fig. 45, then the soffit also must be turned into the vertical plane, as shown at e′ and a line drawn from that point to intersect the projection of the front edge of the jamb in F; join this point to the intersection of the lower edges, and the contained angle is the bevel for the grooves in the soffit. (See Fig. 46.)

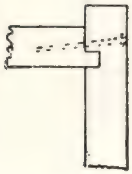


Fig. 46.

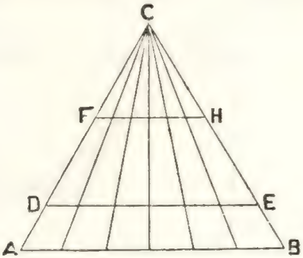


Fig. 47.

The Enlarging and Diminishing of Mouldings. The design of a moulding can be readily enlarged to any desired dimensions by drawing parallel lines from its members, and laying a strip of paper or a straight-edge of the required dimensions in an inclined direction between the boundary lines of the top and bottom edges;

and at the points where the straight-edge crosses the various lines, make marks thereon which will be points in the new projection, each member being increased proportionately to the whole. Projections drawn at right angles to the former from the same points will give data for increasing the width in like manner.

To Diminish a Moulding. The method to be explained, which is equally applicable to enlargement, is based upon one of the properties of a triangle, viz., if one of the sides of a triangle is divided into any number of parts, and lines drawn from the divisions to the opposite side of the triangle, any line parallel with the divided side will be divided in corresponding ratio. See Fig. 47, where A B C is an equilateral triangle, the side A B being divided into six equal parts, and lines drawn from these to the apex C. The two lines D E and F H, parallel to A B, are divided into the same number of parts, and each of these parts bears the same ratio to the whole line that the corresponding part bears to A B, viz., one-sixth; the application of this principle will now be shown. Let it be required to reduce the cornice shown in Fig. 48 to a similar one of smaller proportions. Draw parallel projectors from the various members to the back line A B, and upon this line describe an equilateral triangle. Draw lines from the points on the base to the apex, then set off upon one of the sides of the triangle from C a length equal to the desired height of the new cornice as at G or H, and from this point draw a line parallel to the base line. At the points where this line intersects the inclined division lines, draw horizontal projectors corresponding to the originals. To obtain their length

or amount of projection, draw the horizontal line b E, Fig. 48, at the level of the lowest member of the cornice, and upon this line drop projectors at right angles to it from the various members. Describe the equilateral triangle b i E upon this side, and draw lines from the divisions to the apex i. To ascertain the length

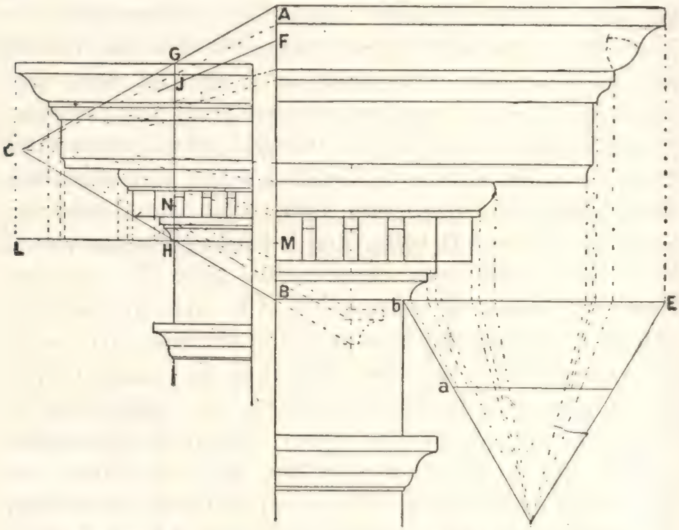


Fig. 49. Fig. 48.

that shall bear the same proportion to b E that the line G H bears to A B, place the length of b E on the line B A from B to F, and draw a line from F to C: the portion of the line G H cut off from J to H is the proportionate length required. Set this length off parallel to b E within the triangle, as before described, and also draw the horizontal line L H, Fig. 49, making it

equal in length to a a, Fig. 48. Upon this line set off the divisions as they occur on a a, noting that their direction is reversed in the two figures. Erect perpendiculars from these points to intersect the previously drawn horizontals, and through the intersections trace the new profile. The frieze and architrave are reduced in like manner, M B, Fig. 48, representing the height of the original architrave, and N H the reduction. The cornice can be enlarged similarly by pro-

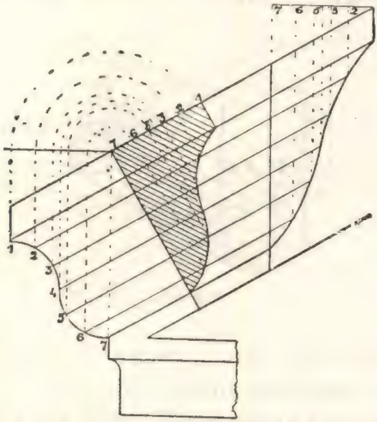


Fig. 50.

ducing the inclined sides of the triangle, as shown by the dotted lines on Fig. 48, sufficiently to enable the required depth to be drawn within it parallel to A B. One member has been enlarged to indicate the method, which should be clear without further explanation.

Raking Mouldings. Fig. 50 shows the method of finding the true section of an inclined moulding that is required to mitre with a similar horizontal moulding

at its lower end, as in pediments of doors and windows. The horizontal section being the more readily seen, is usually decided first. Let the profile in Fig. 50 represent this. Divide the outline into any number of parts, and erect perpendiculars therefrom, to cut a horizontal line drawn from the intersection of the back of the moulding with the top edge, as at point 7. With this point as a centre and the vertical projectors from 1 to 7 as radii, describe arcs cutting the top of the inclined mould, as shown. From these points draw perpendicu-

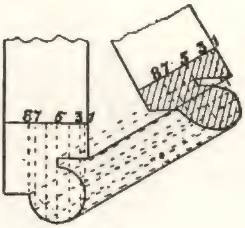


Fig. 51.

lars to the rake, to meet lines parallel to the edges of the inclined moulding drawn from the corresponding points of division in the profile, and their intersections will give points in the curve through which to draw the section of the raking mould. When the pediment is broken and a level moulding returned at the top, its section is found in a similar manner, as will be clear by inspection of the drawing. If the section of the raking moulding is given, that of the horizontal mould can be found by reversing the process described above. Fig. 51 shows the application of the method in finding the section of a return bead when one side is level and

the other inclined, as on the edge of the curb of a skylight with vertical ends.

Sprung Mouldings. Mouldings curved in either elevation or plan are called "sprung," and when these are used in a pediment, require the section to be determined as in a raking moulding. The operation is similar to that described above up to the point where the back of the section is drawn perpendicular to the inclination, but in the present case this line E x, Fig. 52,

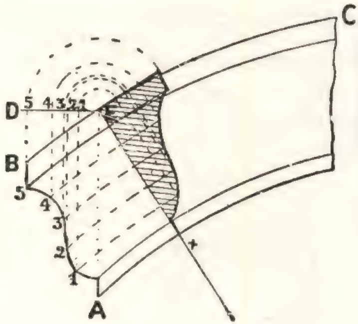


Fig. 52.

is drawn radiating from the centre of the curve, and the projectors are drawn parallel to this line. The parallel projectors, 1, 2, 3, 4, 5, are also described from the centre until they reach the line E x, when perpendiculars to this line are raised from the points of intersection to meet the perpendicular projectors.

Mitreing Straight and Curved Mouldings Together. If a straight mitre is required, draw the plan of the mouldings, as in Fig. 53, and the section of the straight mould at right angles to its plan as at A. Divide its

profile into any number of parts, and from them draw parallels to the edges intersecting the mitre line. From these intersections describe arcs concentric with the plan of the curved mould, and at any convenient point thereon draw a line radial from the centre. Erect perpendiculars on this line from the points where the arcs intersect it, and make them equal in height to the corresponding lines on the section of the straight moulding A, and these will be points in the profile of

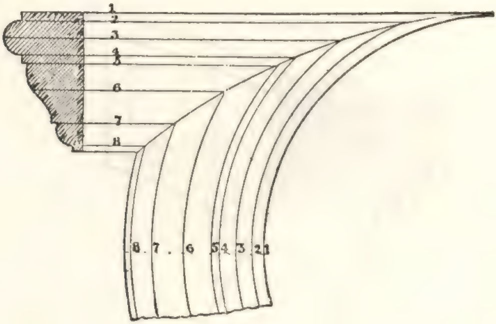


Fig. 53.

the curved moulding B. When it is required that the section of both mouldings shall be alike, a circular mitre is necessary, and its true shape is obtained as shown in Fig. 53. Draw the plan and divide the profile of the straight moulding as before, drawing parallels to the edge towards the seat of the mitre. Upon a line drawn through the centre of the curved moulding set off divisions equal and similar to those on the straight part as 1 to 8 in the drawing. From the centre of the

curve describe arcs passing through these points, and through the points of intersection of these arcs with the parallel projectors, draw a curve which will be the true shape of the mitre. Cut a saddle templet to this shape, and use it to mark the mouldings and guide the chisel in cutting.

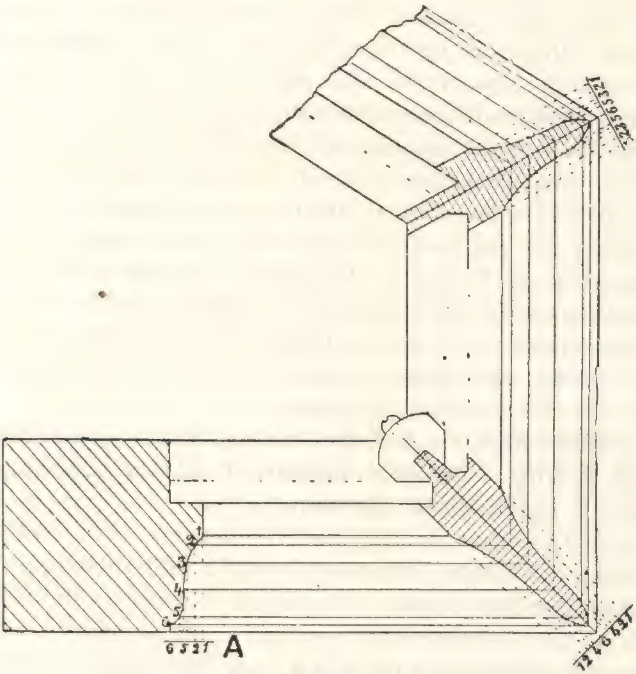


Fig. 54.

To Obtain the Section of a Sash Bar Raking in Plan. Fig. 54 represents the plan of a shop front sash with bars in the angles. On the left hand is shown the sec-

tion of the stile or rail into which the bars have to mitre. Divide the profile of moulding into a number of parts, as shown from 1 to 6, and from these points draw parallels to the sides of the rails intersecting the centre line of the bar. Also draw perpendiculars from the same ponts to any line at right angles to them, as at A. Draw a line at right angles to the centre line of the bar, and on it set off the divisions from 1 to 6 as at A. Draw projectors from these points parallel to the centre line of the bar, and where they intersect the correspondingly numbered lines drawn parallel with the sides of the sash will be points in the curve of the section of the bar. It will be noticed that there is no fillet or square shown on the bar, and that in transferring the points from the line A they must be reversed on each side of the centre. Should a fillet be required on the bar, additional thickness must be given for the purpose. Three methods of forming the rebates in the bar are shown, the screwed saddle beads being the best for securing the glass.

Interior Shutters Include Folding, Sliding, Balanced, and Rolling. Exterior Consist of Hanging, Lifting, Spring, and Venetian Shutters.

FOLDING, or as they are frequently called, BOXING SHUTTERS, because they fold into a boxing or recess formed between the window frames and the walls, are composed of a number of narrow leaves, framed or plain, as their size may determine, rebated and hinged to each other and to the window frames. They should be of such size that when opened out they will cover the entire light space of the sash frame and a margin of a $\frac{1}{4}$ in. in addition. Care must be taken

to make them parallel, or they will not swing clear at the ends; and as a further precaution, they should not be carried right from soffit to window board, but have clearance pieces interposed at their ends about $\frac{3}{8}$ in. thick. The outer leaf, which is always framed, is termed a shutter; the others are termed flaps. It is not advisable to make the shutters less than $1\frac{1}{4}$ in. thick, and flaps over 8 in. wide should be framed; those less than 8 in. may be solid, but should be mitre clamped to prevent warping. In a superior class of work the boxings are provided with cover flaps which conceal the shutters when folded, and fill the void when they are opened out. The sizes and arrangements of the framing are determined by the general finishings of the apartment, but it is usual to make the stiles of the front shutters range with those of the soffit and elbow linings. When venetian or other blinds are used inside, provision is made for them by constructing a block frame from $2\frac{1}{2}$ to 3 in. thick inside the window frame and the shutters are hung to this.

The leaves are hung to each other with wide hinges called back flaps, that screw on the face of the leaves, there not being sufficient surface on the edges for butt hinges. In setting out the depth of boxings, at least $\frac{1}{8}$ in. should be allowed between each shutter to provide room for the fittings; the shutters are fastened by a flat iron bar hung on a pivot plate fixed on the inner left-hand leaf, and having a projecting stud at its other end which fits into a slotted plate, and it is kept in this position by a cam or button. Long shutters are made in two lengths, the joint coming opposite the meeting rails of the sashes; these are sometimes rebated together at the ends.

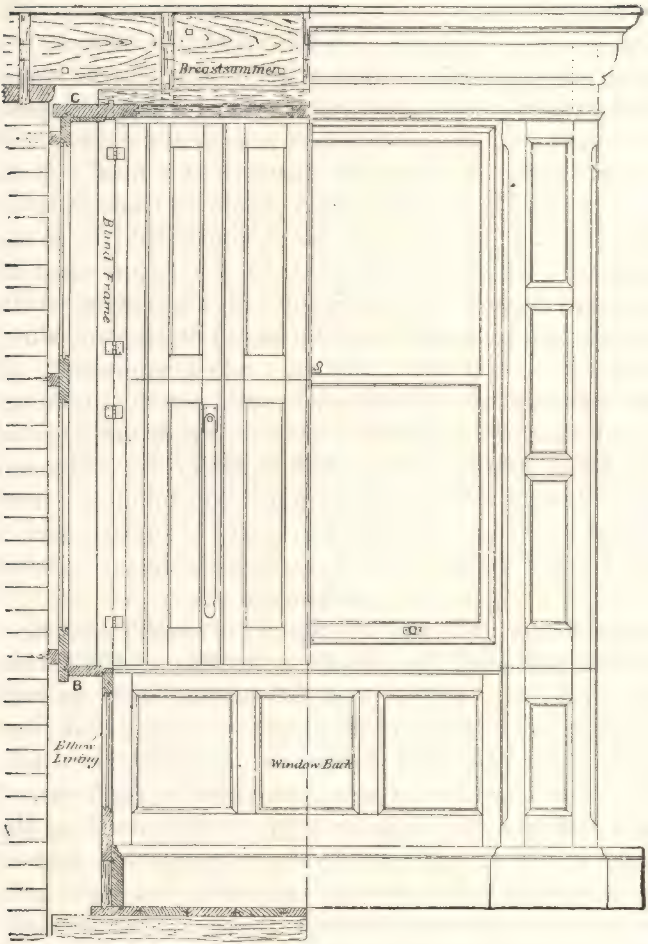


Fig. 55.

Fig. 55 is a sectional elevation of a **Window Fitted with Boxing Shutters** having a cover flap and spaces for a blind and a curtain. One-half of the elevation shows the shutters opened out and the front of the finishings removed, showing the construction of the boxings, &c. The plan, Fig. 56, is divided similarly, one half showing the shutters folded back, with por-

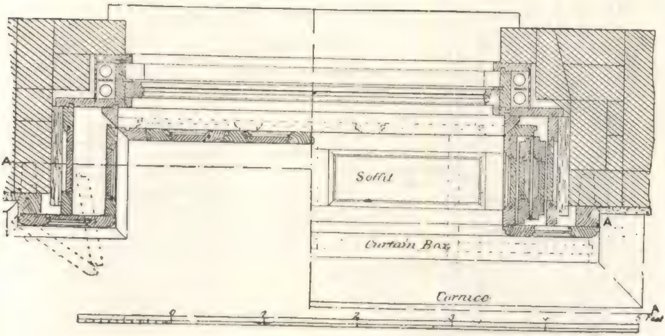


Fig. 56.

tions of soffit cornice, &c.; the other half gives the plan and sections of the lower parts, the dotted lines showing the window back.

Fig. 57 is a vertical section and Fig. 58 an enlarged section through the boxings. The framed pilaster covering the boxing is cut at the level of the window board, and hung to the stud A′, this being necessary for the cover to clear the shutters when open (see dotted lines on opposite half). The cover flap closes into rebates at the top and bottom, as shown in sec-

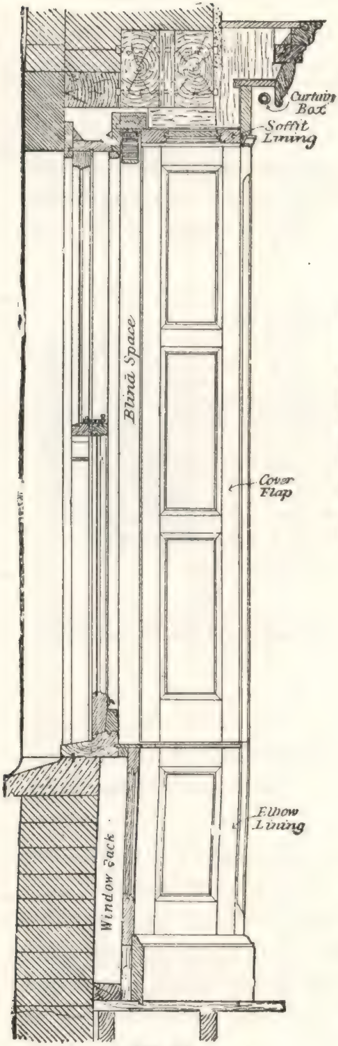


Fig. 57.

tion in Fig. 55. The window back is carried behind the elbows, and grooved to receive the latter. The rails of the soffit must be wide enough to cover the boxings, and should have the boxing back tongued

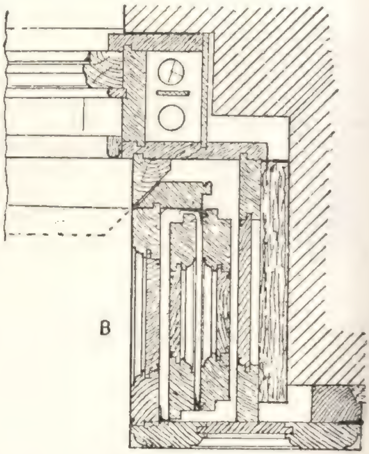


Fig. 58.

into it, as shown in the section, Fig. 55. When the linings of an opening run from soffit to the floor uninterruptedly, they are called jamb linings; but when they commence, as in the present instance, under the

window board, they are termed elbow linings, the corresponding framing under the window being the window back.

Sliding Shutters are used instead of folding shutters in thin walls, and consist of thin panelled frames running between guides or rails fixed on the soffit and window board, which are made wider than usual for

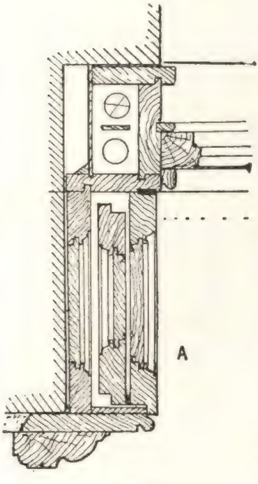


Fig. 59.

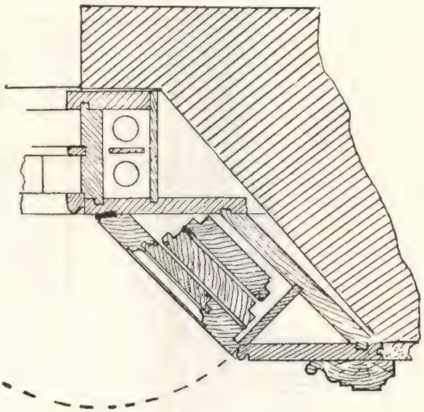


Fig. 60.

that purpose. When open, they lie upon the face of the wall adjacent to the opening. They are so seldom used that they do not call for illustration.

Balanced or Lifting Shutters are shown in section in Fig. 61, and plan in Fig. 62. They consist of thin panelled frames, the full width of and each half the height

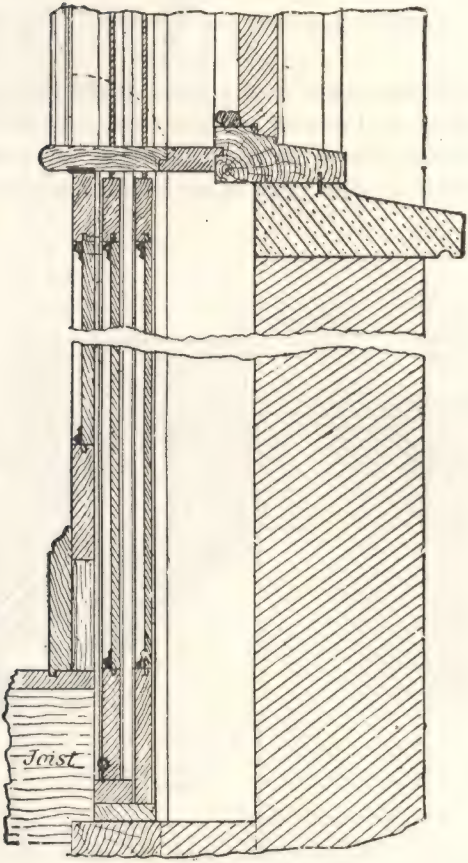


Fig. 61.

f the window, hung with weights in a cased frame in a similar manner to a pair of sashes. The frame extends the whole height of the window, and is carried down behind the floor joists to the set off. The win-

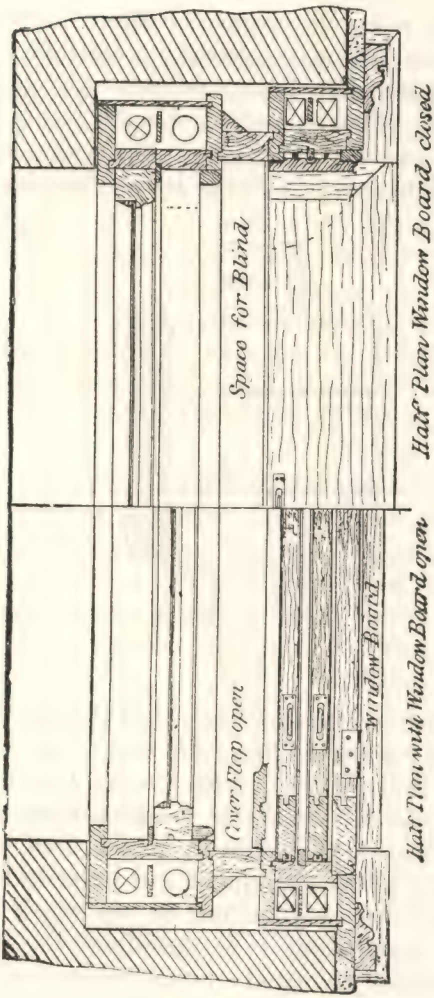

Space for Blind
Half Plan Window Board closed
Cover Flap open
Window Board
Half Plan with Window Board open

Fig. 62.

dow board is hinged to the front panelling or shutter back, so that when the former is lifted, the shutters can pass down behind the back out of sight. Cover flaps hung to the outer linings on each side close over the face of the pulley stiles and hide the cords. When it is desired to close the shutters, the cover flaps are opened out flat, as shown to the left of the plan. The

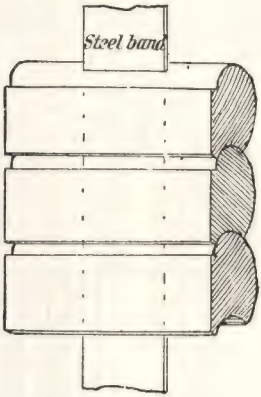


Fig. 63.

window board can then be lifted, and the shutters run up, a pair of flush rings being inserted in the top edge of each for that purpose. The window board is next shut down, the inside shutter brought down upon it, the outside one pushed tight up to the head, and the meeting rails, which overlap an inch, fastened with a thumb-screw. The bottom rail of the upper shutter is made an inch wider than the other, for the purpose of showing an equal margin when overlapped. Square lead weights have generally to be used for

these shutters in consequence of their comparative heaviness.

Rolling or Spring Shutters are made in iron, steel and painted or polished woods, and though somewhat monotonous in appearance, are, in consequence of their convenience in opening and closing, and in the case of the metal kinds, the additional security against fire and burglary, fast superseding all other kinds, both for internal and external use, especially in shops and public buildings. They consist, in the case of the wood varieties, of a series of laths of plano-convex, double convex, oval, or ogee section, fastened together by thin steel or copper bands passing through mortises in the centre of the thickness, as shown in Fig. 63, and secured at their upper ends to the spring container. These metal bands are supplemented by several waterproof bands of flax webbing glued to the back sides of the laths. The upper edge of each lath is rounded, and fits into a corresponding hollow in the lower edge of the one above it; this peculiar overlapping joint, whilst preventing the passage of light, etc., between the laths, readily yields when the shutter is coiled around the barrel. The spring barrel is usually made of tinned iron plate, and encases a stout spiral spring wound around an iron mandrel with squared ends to which a key is fitted for winding the spring up. The ends of the mandrel project from the case and are fixed in bracket plates at each end of the shutter—in the case of shop fronts, in a box or recess behind the fascia; one end of the spring is secured to the barrel, the other end to the mandrel; the shutter is secured to the barrel by the metal bands mentioned

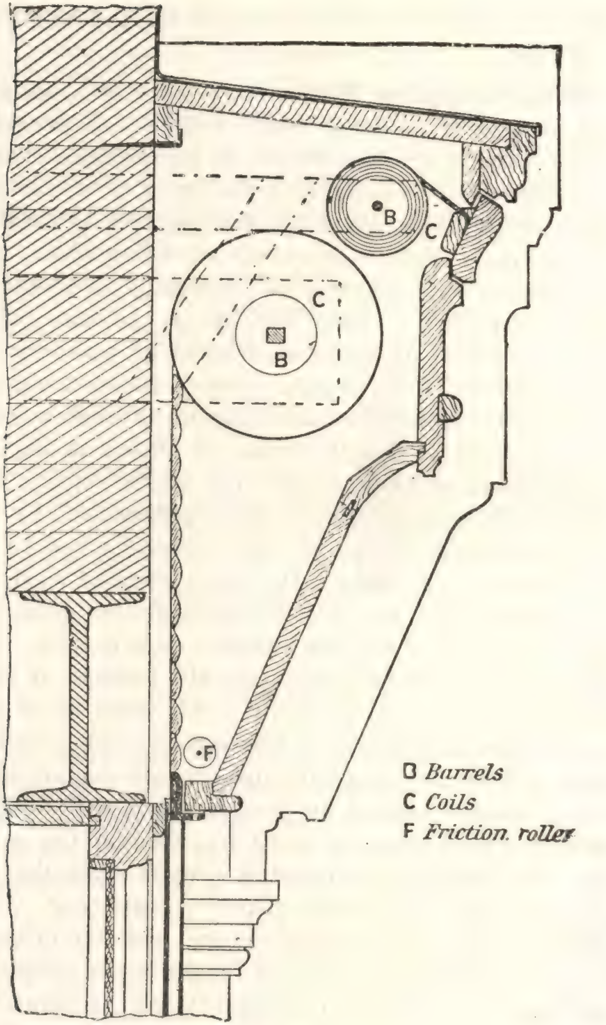


Fig. 64.

above, and the normal condition of things is that when the shutter is coiled up the spring is unwound. The pulling down of the shutter winds up the spring, and the tension is so arranged that it does not quite overcome the weight of the shutter and the friction when the shutter is down, so that the latter must be assisted up with a long arm. Great care should be taken in fixing these shutters to arrange the barrel perfectly level and parallel with the front, and to securely fix the brackets. These may be bolted to the girder or breast-summer, or screwed to the fixings plugged in the wall, as shown by dotted lines in Fig. 64. Where possible a wood groove should be formed on each side of the openings for the shutters to work in, but iron channels (Fig. 65) are frequently used. These are cemented into a chase in the wall or pilaster. Fig. 64 is a section through a shop fascia, showing shutter and blind barrels fixed to the face of the wall, where no provision has been made beneath the girder. Fig. 66 shows the adaption of one of these shutters to the inside of a window; the barrel is fixed in a seat formed beneath the window, the top of which is hinged, to gain access to the coil. The minimum space required for a coil, for a shutter about 6 ft. high is $10\frac{1}{2}$ in. A friction roller F should be fixed close to the back rail to prevent chafing as the coil unwinds; the shutter is lifted by means of a flush ring in the L iron bar at the top, and this ring engages with a tilting hook in the soffit to keep the shutter up. The metal varieties of these shutters are wound up by the aid of balance weights or bevel wheel gearing.

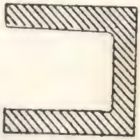


Fig. 65.

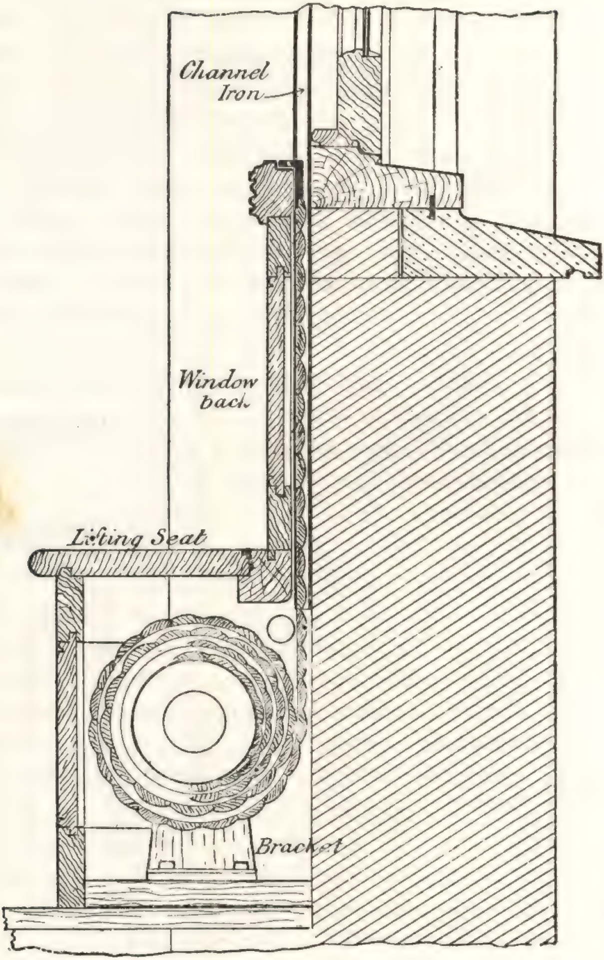


Fig. 66.

WINDOWS GENERALLY.

Size and Position. The size and position of window openings are influenced by the size of the rooms, and the purposes for which the building is used. For the sake of ventilation, and also to secure good lighting, the windows should be placed at as great a height as the construction of the room will allow. In dwelling-houses the height of the sill is usually about 2′ 6″ above the inside floor level.

Construction. The framework holding the glass of the window may be fixed or movable. It must be so prepared that the glass can be replaced easily when necessary. In warehouses, workshops and similar buildings, the frames holding the glass are often fixed as **Fast Sheets** (Fig. 66½). As, however, this arrangement affords no means of ventilation, it is more usual to have the glass fixed in lighter frames called **Sashes**. If the sashes are hung to solid rebated frames, and open as doors do, the windows are called **Casement Sashes.** If they slide vertically and are balanced by weights or by each other, the window is a **Sash and Frame Window.** Other methods of arranging sashes, either hinged, pivoted or made to slide past each other, are described in detail later.

Sashes. The terms used for the various parts of sashes and fast sheets are somewhat similar to those employed in describing doors. Thus, the **Styles** are the outer uprights, and the **Rails** are the main horizontal cross-pieces: top rails, meeting rails, and bottom rails being distinguished. Any intermediate members, whether vertical or horizontal, are named **Bars.**

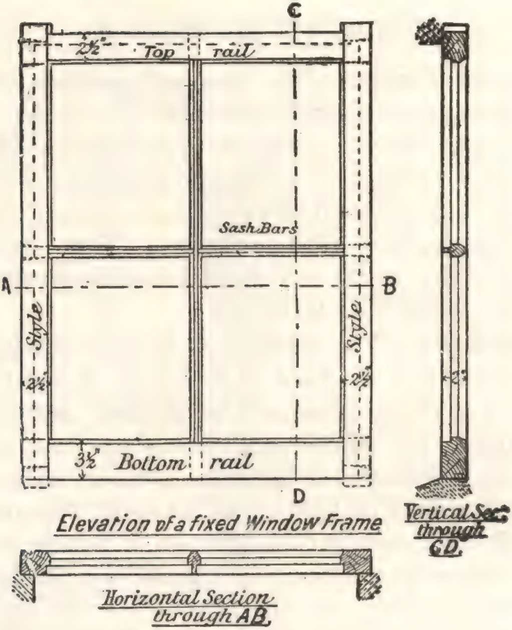


Fig. 66½.

Sashes are from $1\frac{1}{2}$ to 3 inches thick. The inner edge of the outer face is **Rebated** to receive the glass. The inner face is left either square, chamfered, or moulded;

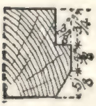


Fig. 67.

Fig. 68.

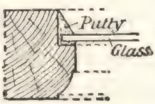


Fig. 69.

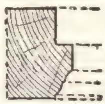


Fig. 70.

two common forms of moulding are lamb's-tongue (Fig. 68) and ovolo (Fig. 69). The size of the rebate is indi-

cated in Fig. 70; it varies with the thickness of the sash, its depth being always a little more than one-third this thickness. The width of the rebate varies from a quarter of an inch to half an inch, and the mould is usually sunk the same depth as the rebate. This last fact is of some importance, as it affects the shoulder lines; and with hand work it influences the amount of labor in the making of the sashes.

As little material as possible is used in the sashes, in order that the light shall not be interfered with. In general, the styles and top rail are square in section before being rebated and moulded. In casement sashes, however, it is often advisable to have the outer styles a little wider than the thickness, especially when they are tongued into the frame. The width of the bottom rail is from one and a half to twice the thickness of the sash. Sash bars which require rebating and moulding on both sides, should be as narrow as possible, in order not to interrupt the light. They are usually from five-eighths of an inch to one and a quarter inches wide.

Joints of Sashes. The sashes are framed together by means of the **Mortise and Tenon Joint** (Fig. 71). The proportions of the thickness and width of tenons, haunched tenons, &c., are to a large extent applicable here. Hardwood cross-tongues are sometimes inserted to strengthen the joints while thick sashes should have **Double Tenons.** An alternative to halving in sash bars is to arrange that the bar which is subjected to the greater stress—as for example, the vertical bars in sliding sashes, and the horizontal bars in hinged casement sashes—shall be continuous; this continuous bar is mortised to receive the other, which is

scribed i. e. cut to fit the first, and on which the short tenons are left. This method is called **Franking the Sash Bars,** and is illustrated in Fig. 72.

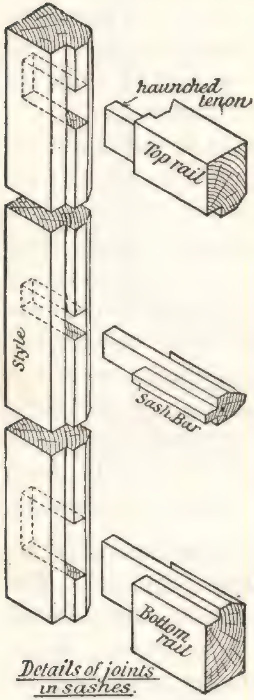


Fig. 71.

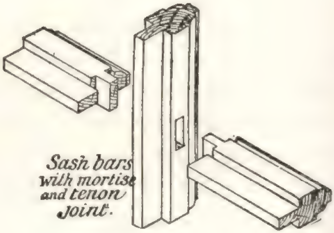


Fig. 72.

Casement Windows. Casement windows may be hinged in such a manner that they open either inwards or outwards. They may consist either of one sash, or of folding sashes, and are hung with butt hinges to solid rebated frames. These **Frames** consist of jambs, head

and sill. The head and sill "run through" and are mortised near the ends to receive tenons formed on the ends of the jambs. The upper surface of the sill is weathered to throw off rain water. Casement windows which reach to the floor are usually called **French Casements.** Their sashes require an extra depth of bottom rail.

Casement Sashes Opening Inwards. Figs. 73, 74 show the elevation and vertical and horizontal sections, of a window opening in a 14″ brick wall fitted with a casement window having folding sashes to open inwards. In this class of window the frame is rebated for the sashes on the inner side. Each sash has, on the outer edge of the outer style, a semi-circular tongue, which fits into a corresponding groove in the jamb of the frame. This tongue renders the vertical joint between the sash and frame more likely to be weather proof; it is to provide for the tongue that the extra width of style already referred to is necessary. The tongue, however, is often omitted, as in Fig. 77. It will be seen readily that, if the sash were in one width, it would be impossible to have a tongue on more than one edge of it. With casement sashes opening inwards the greatest difficulty is found, however, in making a water-tight joint between the bottom rail of the sash and the sill of the frame. Figs. 77 and 78 show two methods by which this may be accomplished. An essential feature of all these sashes is a small groove or **Throating** on the under edge of the bottom rail; this prevents the water from getting through. The groove in the rebate of the sill (Fig. 78) is provided to collect any water that may drive through the joint. This

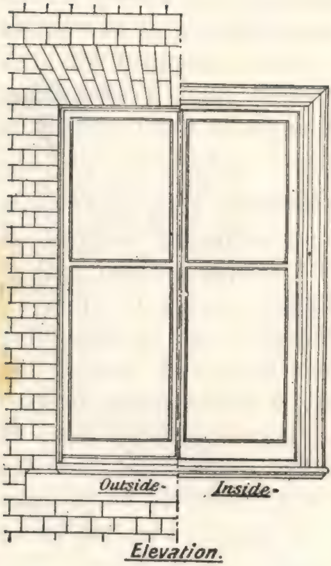


Fig. 73.

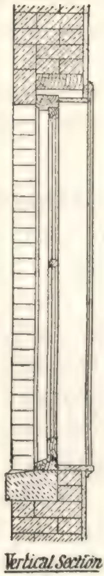


Fig. 74.

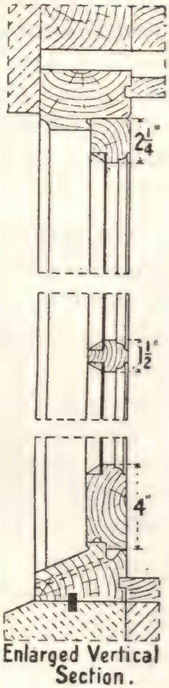


Fig. 75.

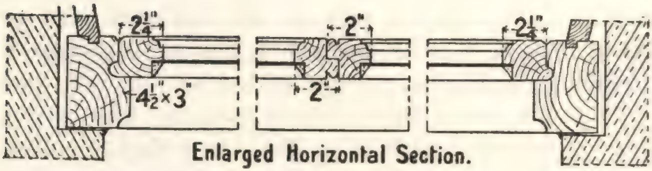


Fig. 76.

water escapes through the hole bored in the center of the sill.

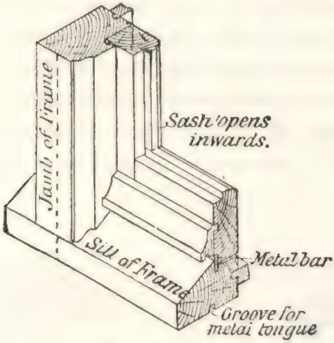


Fig. 77.

When casement sashes are hung after the manner of folding doors, the vertical joint between the meeting styles is rebated. Alternative methods of rebating

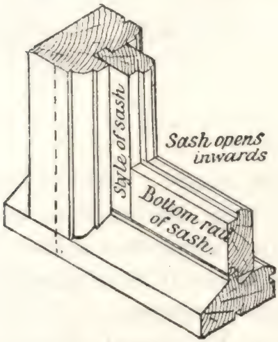


Fig. 78.

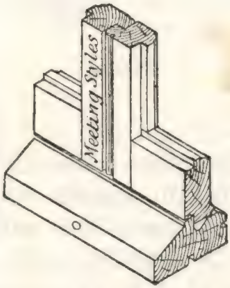


Fig. 79.

are shown in Fig. 79 and 80. Fig. 80 is known as a **Hook Joint** and is the better one.

Casement Sashes Opening Outwards. These are more easily made weatherproof than inward-opening sashes. The chief objections to their adoption are that they are not easily accessible for cleaning the outside, especially in upper rooms and that they are also liable, when left open, to be damaged by high winds and to let in the rain during a storm. Fig. 81 is a sketch of one corner of such a window. It will be noticed that these

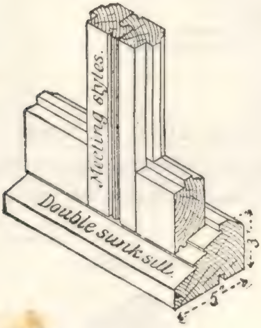


Fig. 80.

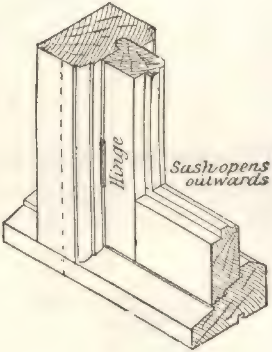


Fig. 81.

frames, like door frames, have the exposes arrises moulded in various ways, and that the sashes may either be hung flush with one face of the frame (as in Figs. 76 and 77), or fit in the thickness of the frame (Figs. 78 and 81). The sill shows to be **Double Sunk,** i. e., to have the upper surface—upon which the bottom rail of the sash fits—rebated with two slopes (weatherings).

Sash and Frame Window. In this class of window, which is by far the most common, because it is easily made weatherproof, there are **Two Sashes,** which slide past each other in vertical grooves, and are usually balanced by iron or leaden weights. As will be seen from Fig. 82 the frames form cases or boxes in which the weights are suspended. They are hence called

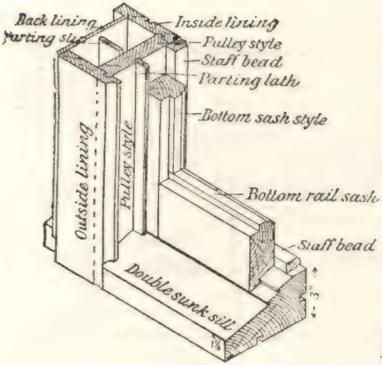


Fig. 82.

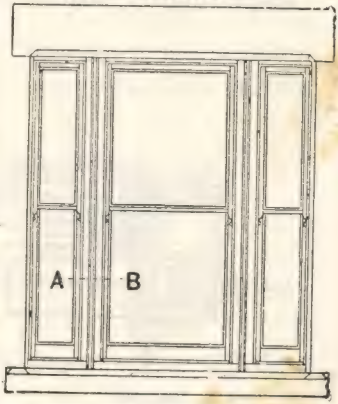


Fig. 82½.

Cased Frames. **Pulley Styles** (Fig. 86) take the place of the solid rebated jambs of casement windows. The pulley styles, **Outside** and **Inside Linings,** and **Back Lining** (Fig. 82) together form a box which is subdivided by a vertical **Parting Slip** suspended as shown in Fig. 82. In superior window frames of this kind, the pulley styles and linings are tongued and grooved together as shown in Fig. 83. In commoner work the tongues and grooves are often omitted. The frame

must be so constructed that the sashes can be removed easily for the purpose of replacing broken sash-lines. To enable this to be done, the edge of the inside lining is either made flush with the face of the pulley style (Fig. 83), or it is rebated slightly as shown in Fig. 83. The edge of the outside lining projects for a distance of about three-quarters of an inch beyond the face of the pulley style, to form a rebate against which the **outer** (upper) sash slides. The outer sash is kept in

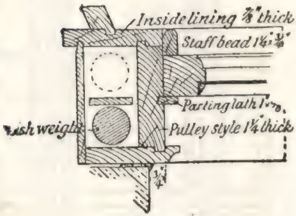


Fig. 83.

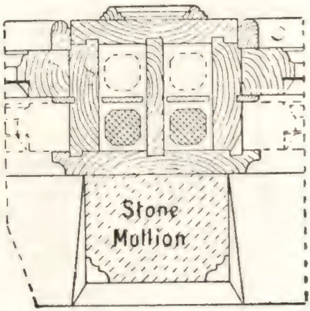


Fig. 83½.

position by the **Parting Lath** (Fig. 82) which fits into a groove in the pulley style. The groove for the inner (lower) sash is formed by the parting lath and a **Staff Bead** or **Stop Bead** which is secured by screws. The staff bead on the sill is often made from two to three inches deep to allow the lower sash to be raised sufficiently for ventilation at the meeting rails without causing a draught at the bottom (Fig. 83).

A vertical section through the head of the frame is similar to a horizontal section across the pulley style,

except that the back lining and parting slip are of course absent.

The sill of the frame is solid and weathered, and should always be of hardwood, preferably oak or teak. The sill has a width equal to the full thickness of the frame. When the weathering has two steppings, it is known as a **Double Sunk Sill.** An alternative to the plan of having the width of the sill of the full thickness of the frame, is to arrange it so that the outside edge is flush with the outside face of the bottom sash, as shown in Fig. 89. With a sill arranged in this manner, and double sunk, there is less danger of water driving

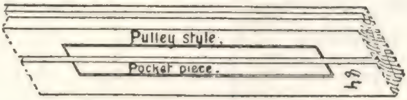


Fig. 84.

through the joint between the sash and the sill than with a sill the full thickness of the frame. In order to render watertight the joint between the wooden and stone sills of window frames, a metal tongue is often fixed into corresponding grooves cut into the under side of the wooden sill and the upper surface of the stone sill. A rebated joint between the two sills serves the same purpose as the metal tongue.

Fig. 84 shows the methods of fixing the pulley style into the head and sill respectively, when the width of the sill is equal to the full thickness of the frame. The **Pulleys** on which the sash lines run—sash or axle pulleys are fixed in mortises near the upper ends of the

pulley styles. It is also necessary to have a removal piece in the lower part of each pulley style, to allow of access to the weights. This piece is named the **Pocket Piece.** It may be cut as shown in Fig. 85; its position is then behind the lower sash, and it is hidden

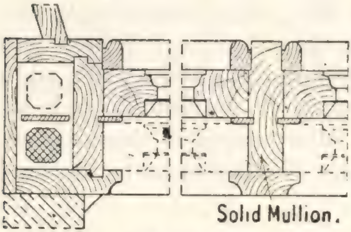


Fig. 84½.

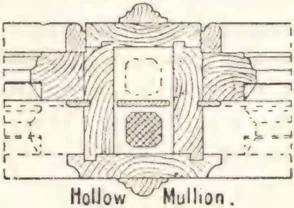


Fig. 85½.

from view when the window is closed. Or, the pocket piece may be in the middle of the pulley style as shown in Fig. 84; the vertical joints between the pocket piece and the pulley style are then V shaped to prevent damage to the paint in case of removal.

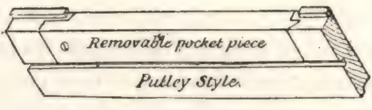
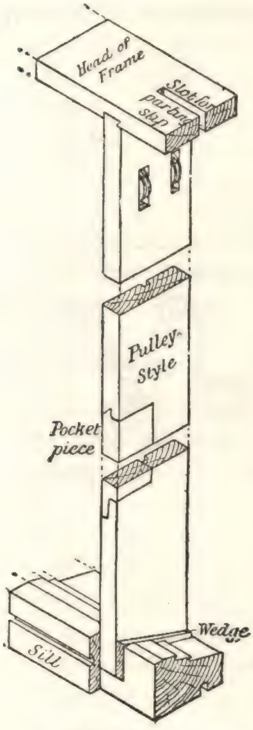


Fig. 85.

Sashes. The only difference between the joints of sliding sashes and those of the casement sashes already described is in the construction of the meeting rails. Each of the meeting rails is made thicker than the sash to the extent of the thickness of the parting lath; otherwise there would be a space between them equal to the

thickness of the parting lath. The joint between them may be rebated or splayed. The angle joints between the ends of the sash styles and the meeting rails are



-Joints at ends of Pulley Style.

Fig. 86.

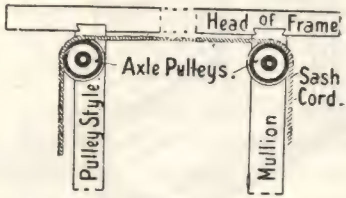
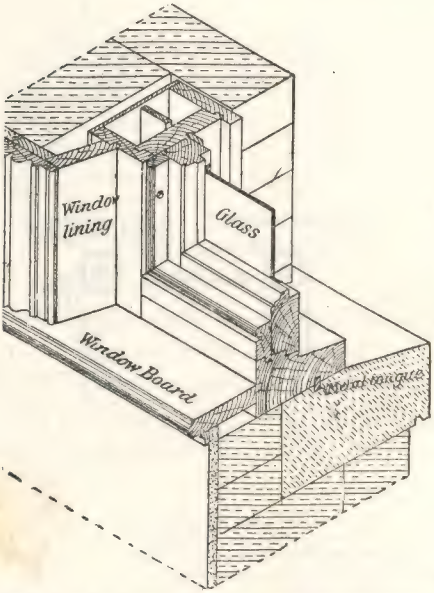


Fig. 86½.

often dovetailed as shown in Fig. 86. They are, however, stronger if the styles are made a little longer, the projecting part being moulded, and mortise and

tenon joints used as shown in Figs. 86 and 87. The projecting ends of the styles are called **Joggles**; they assist in enabling the sashes, especially in wide windows, to slide more freely. When as is usually the case, both sashes slide and are balanced by weights, the



Sketch of one corner of a Sash and Frame Window.

Fig. 87.

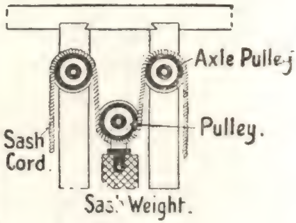


Fig. 87½.

window is known as a **Double-Hung** sash and frame window. If one sash only slides, and the other is fixed in the frame, the window is **Single-Hung**. Figs. 78 to 80 show the details of a sash and frame window fixed in a one-and-a-half-brick-thick wall and having a stone head and sill.

For the sake of appearance, or when it is required to have wider windows than can be arranged with one pair of sashes, two or three pairs of sashes are often constructed side by side in the same frame. When three pairs of sashes are used, it is usual to have the middle pair wider than the others; such a combination (Fig. 73) is named a **Venetian Window.** The vertical divisions between adjacent pairs of sashes are called **Mullions.** These mullions may be constructed in several different ways. If the middle pair of sashes only is required to slide, the mullions may be solid from 1¼″ to 2″ thick, and the sash-cord conducted by means of additional pulleys to the boxes, which are at the outer edges of the frame. Figs. 84 and 86 show this arrangement. If it is desirable to have all the sashes to slide, the mullions must be hollow to provide room for the weights. Figs. 85 and 87 show details of a mullion with provision made for one weight to balance the two sashes adjacent to it. With this arrangement the sash-cord passes round a pulley fixed into the upper end of the weight. If stone mullions are used in the window opening, separate boxings may be made so that each pair of sashes is hung independently as shown in Fig. 83, and the window becomes, as it were, two or three—as the case may be—separate window frames, with the sill and head each in one length for the sake of strength.

The Hanging of Vertical Sliding Sashes. As shown in illustrations already given, the sashes of sash and frame windows are balanced by cast-iron or leaden weights. The best cord is employed for hanging sashes of ordinary size, while for very heavy sashes the sash

lines are often of steel or copper. The staff bead and parting bead having been removed, the cords are passed over the axle pulleys (which are best of brass to prevent corrosion) and are tied to the upper ends of the weights. The weights are passed through the pocket holes and suspended in the boxes. The pocket pieces having been replaced, the upper sash, which slides in the outer groove, is hung first, the free ends of the cords being either nailed into grooves in the outer edges of the sash or secured by knotting the ends after passing them through holes bored into the styles of the sash. The upper sash having been hung, the parting laths are fixed into the grooves in the pulley styles, and the lower (inner) sash is hung in a similar manner, after which the staff beads are screwed in position. Care should be taken to have the cords of the right lengths; if the cords for the upper sash are too long the weights will touch the bottom of the frame, and cease to balance the weight of the sash before the latter is closed. If the cords for the lower sash are too short, the weights will come in contact with the axle pulleys, and thus prevent it from closing. Several different devices for hanging sashes—the objects of which are either to render unnecessary the use of weights or to facilitate the cleaning of the outside of the window—have been patented, and are in more or less general use. A detailed description of these is, however, beyond the scope of this book.

Bay Windows. A bay window is one that projects beyond the face of the wall. The side lights may be either splayed or at right angles to the front. The window openings may be formed by having stone or

brick mullions or piers at the angles, against which the window frames are fixed, or the wooden framework of the window may be complete in itself. When the latter is the case, it is usual to have stone or brick

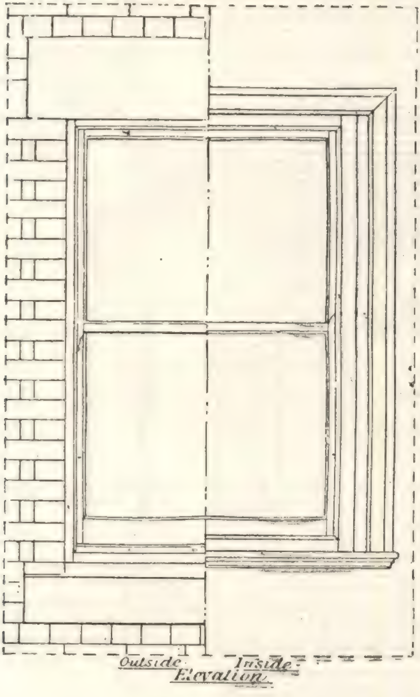


Fig. 88.

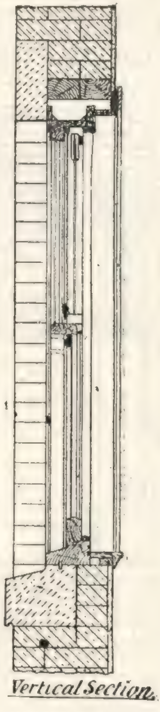
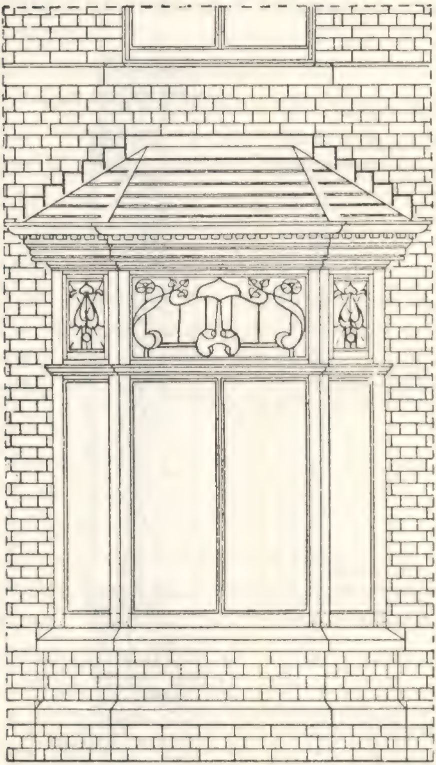


Fig. 89.

work to the sill level as shown in Fig. 88. Bay windows naturally lend themselves to decorative treatment. With the addition of masonry or brickwork they often assume a massive and bold appearance. When

usually by a wooden cornice, and the wooden roof is covered with lead, slates or tiles. The window frames may be arranged as fixed lights, sash and frame, or



Front Elevation.
Fig. 88½.

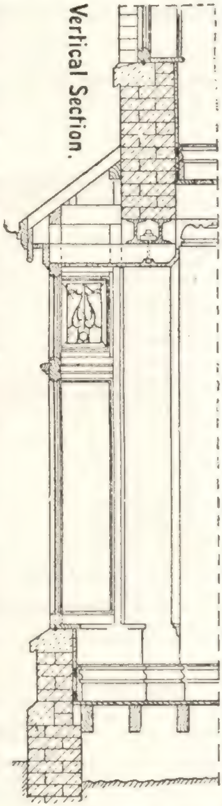
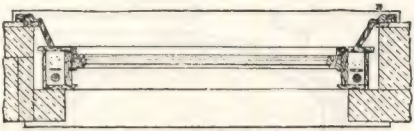


Fig. 89½.

casements. The most usual arrangement is to have the lower lights fixed, and the upper ones as sashes hinged to open for ventilating purposes. Figs. 88 to 90

show the details of a bay window with splayed side lights, the upper side lights being hinged on the transom to open inwards.

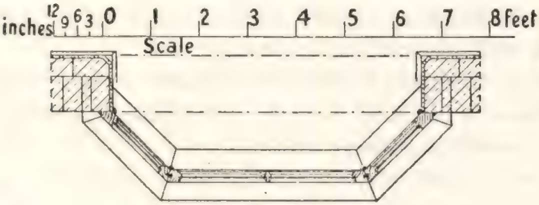
Windows With Curved Heads. When a window opening is surmounted by an arch, the top of the window frame requires to be off the same curvature as the under side (soffit) of the arch. In the case of fixed



Horizontal Section.

Fig. 90.

sashes, or of solid frames with casement sashes, the head of the frame is "cut out of the solid." A head which, owing to the size of the curve, cannot easily be obtained in one piece, is built up of segments, the

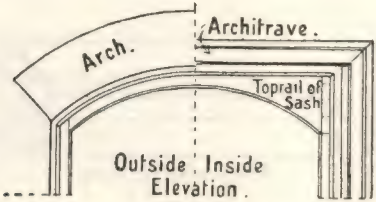


Horizontal Section.

Fig. 90½.

joints being radial to the curve, and secured by hardwood keys. As an alternative method, the head may be built up of two thicknesses—with overlapping joints—and secured together by screws.

A sash and frame window in such an opening may have only the outside lining cut to the curve of the arch, the inner side of the frame being left square. The upper sash will then require a top rail with a straight upper edge and a curved lower edge, as shown in Fig. 91.



Elevation of upper part of a Window having Curved Head.

Fig. 91.

When the head of the frame has to be curved, it may

(1) be built up of two thicknesses with overlapping joints, and secured by screws; it may

(2) be formed of three thicknesses of thin material, bent upon a block of the correct radius, and well glued and screwed together; or

(3) the head may be of the same thickness as the pulley styles, with trenches cut out of the back (upper) side, leaving only a veneer on the face-side under the trenches. Wooden keys are glued and driven into the trenches after the head has been bent upon a block to the required shape.

A strip of stout canvas glued over the upper side will strengthen the whole materially. The outside and

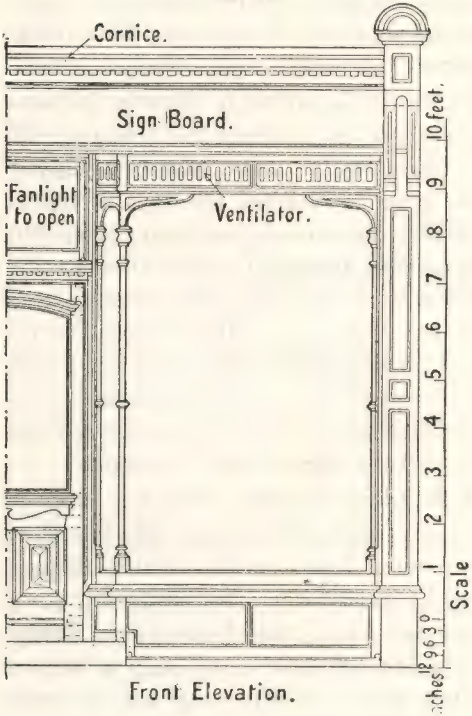
inside linings are in such a case cut to the required curvature, and when nailed in position hold the head in shape. The end joints of the linings may have hardwood cross-tongues.

Shop Windows. The main object in view in the construction of shop windows is to admit the maximum of light, and to give opportunity for an effective display of the goods. The glass is in large sheets, and therefore is especially thick to secure the necessary strength. Shop windows are usually arranged as fast sheets, with provision for ventilation at the top. The glass is held in position by wooden fillets, and is fixed from the inner side. The chief constructional variations are found in the pilasters, cornice, provision for sign-board, sunblind, and the arrangement of the side windows. Figs. 92 to 95 show the details of a typical example.

The Fixing of Window Frames. Window frames may be built into the wall—which has usually a recessed opening to receive them—as the brickwork proceeds, or they may be fixed later. In the former case, the ends of the sill and head project and form **Horns**, which are built into the brickwork and help to secure the frame. Wooden bricks or slips may also be built into the wall, the frames being nailed to them.

In the latter case, the frames are secured by wooden **Wedges**, which are driven tightly between the frame and the wall. These wedges should be inserted only at the ends of the head and sill and directly above the jambs; otherwise the frame might be so strained as to interfere with the sliding of the sashes. Window frames as well as door frames should be bedded against a layer of hair-mortar placed in the recess.

Fig. 92.



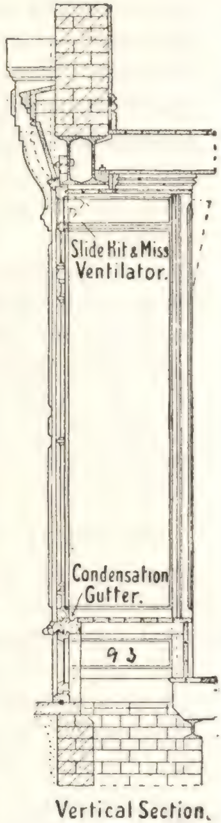


Fig. 93.

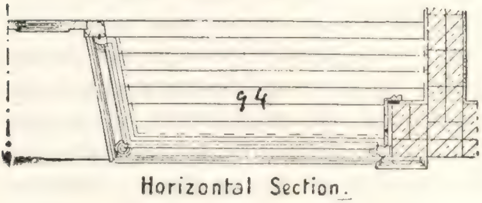
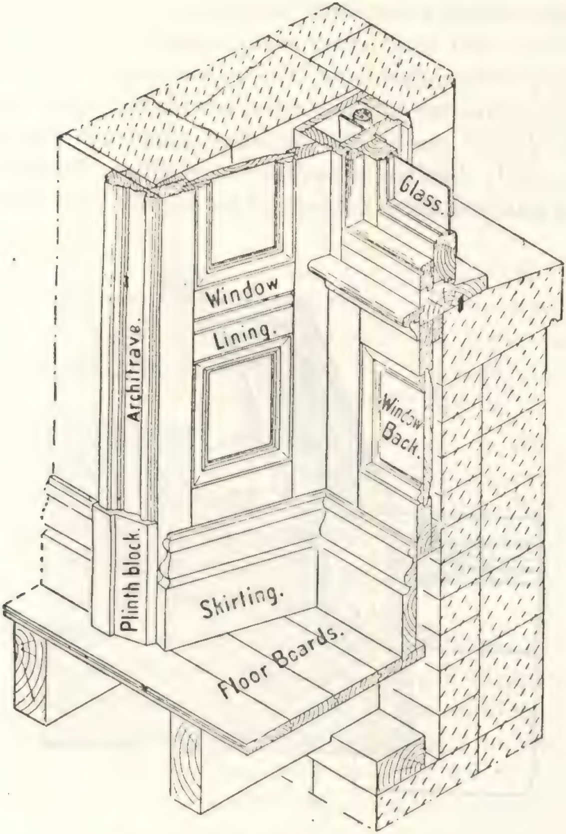


Fig. 94.



Sketch of part of a Sash and Frame Window, showing Panelled and Moulded Jamb-lining, etc.

Fig. 95.

Linings. When window frames are not of sufficient thickness to come flush with the inner face of the wall, the plaster may be returned round the brickwork and

finished against the frame, or a narrow fillet of wood may be scribed to the wall and nailed to the frame. In dwelling-houses, however, the more usual way is to fix linings similar to those used for outer door frames. The width of the linings depends upon the thickness of the wall; they should project beyond the inner face of the wall for a distance equal to the thickness of the

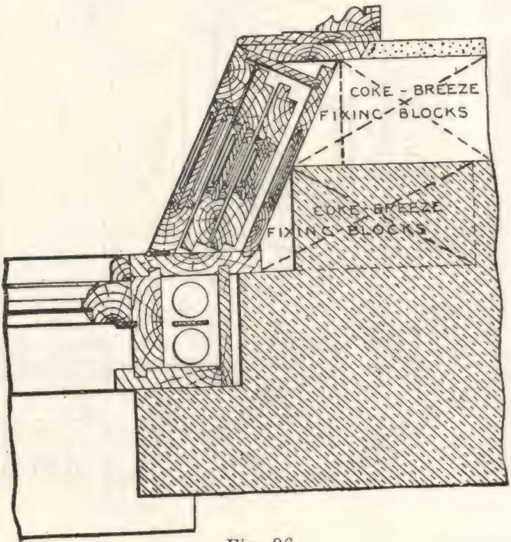


Fig. 96.

plaster, and are usually splayed so that they will not interfere with the admission of light. The inside of window and door openings usually are finished similarly; thus, the **Architrave,** or **Band Moulding,** which is secured to the edge of the linings and to rough wooden **Grounds** is fixed along the sides and top in both cases.

The bottom of the window opening is finished with a **Window Board** which is tongued into the sill of the frame. The board is about $1\frac{1}{4}$ inches thick, and is made wide enough to project beyond the surface of the plaster for a distance of about 18 inches. The projecting edge is nosed (rounded) or moulded. It is longer than the opening, to allow the lower ends of the architrave to rest upon it.

When the walls are thick, the linings are often framed and panelled. Such linings may terminate on a window board at the sill level, or the inner side of the wall may be recessed below the sill level and the linings carried to the floor as shown in Fig. 96.

Window Shutters. Although not used to the same extent as formerly, wooden window shutters are fitted occasionally to close up the window opening. Window shutters, which are arranged generally on the inner side of the window, may be hinged as box shutters, or may be vertically sliding shutters.

Box Shutters consist of a number of leaves or narrow frames which are rebated and hinged together, an equal number being on each side of the window opening, the outer ones on each side being hung to the window frame. When closed they together fill the width of the window-space, and when open they fold behind each other so that the front one forms the jamb lining of the window frame. If the walls are thick, the shutters can be arranged to fold in the thickness of the wall; if the wall is a thin one it is necessary to construct projecting boxes into which the shutters fold. The nature of the framing of the shutters depends upon the surrounding work; it is usual to have the outer sur-

face framed and moulded, and the inside finished bead-flush. The arrangement of box shutters requires that the shutters on the same side shall vary in width so that they will fold into the boxes on each side of the window, the outermost shutter (which is the widest) then acting as the window lining. Fig. 96 shows a horizontal section through one side of a window, showing hinged shutters folding so that a splayed lining is obtained. Fig. 97 shows hinged shutters consisting of one narrow and one wide shutter on each side of the

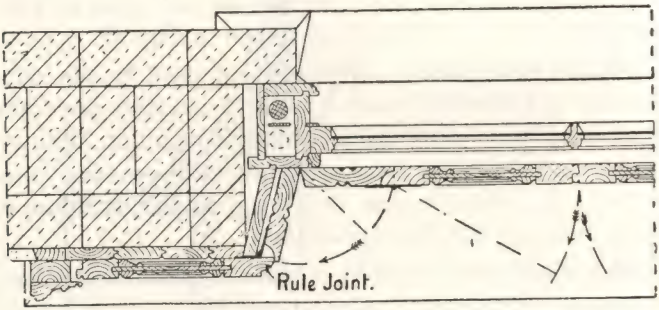


Fig. 97.

opening. This arrangement is suitable for a thin wall, where it is undesirable to have boxes for the shutters projecting beyond the face of the wall. For hanging window shutters it is usual to use back-flap hinges; the joint at the corner of the shutters in Fig. 97 is named a rule joint.

Sliding Shutters, working in vertical grooves and balanced by weights, are sometimes used. They require that the wall under the window sill shall be recessed; the floor also often needs trimming to allow

space for them to slide sufficiently low. To hide the grooves in which the shutters slide, thin vertical flaps are hung to the window frame, and the window board is also hinged at the front edge to allow the shutters to slide be-

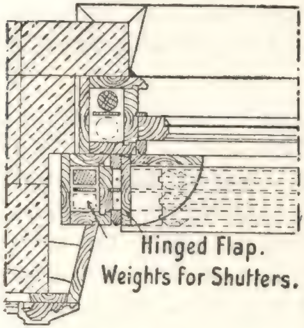


Fig. 99.

low the sill. Figs. 98 and 99 are sections of vertical sliding shutters.

Hinged Skylights.

Skylights which are hinged to open are fitted upon the upper edge of a **Curb** or frame fixed in the plane of the roof, the com-

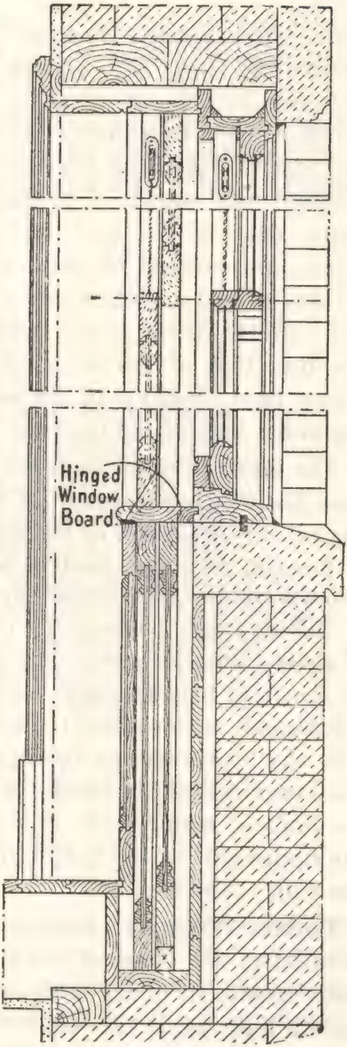


Fig. 98.

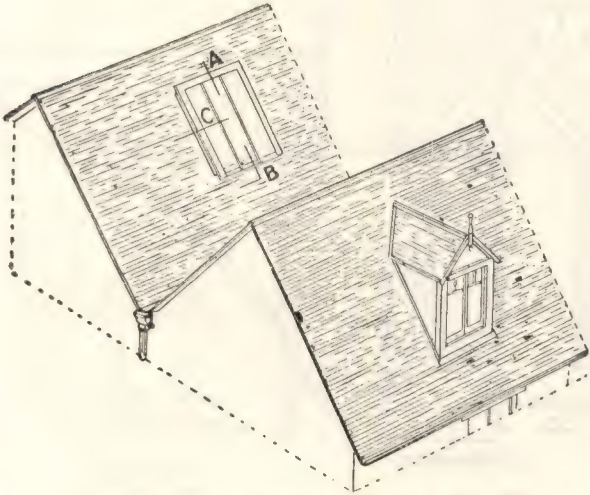
mon rafters being "trimmed" to the required size to receive the curb. The curb is made from material 1¼ to 2 inches thick, and of width such that its upper edge stands from 4 to 6 inches above the plane of the roof. The **Angle Joints** of the curb may be dovetailed or tongued and nailed. The **Sash Frame** rests upon the upper edge of the curb; it is from 2 to 2½ inches thick, and consists of stiles and top rail of the same thickness, and a bottom rail which is thinner than the stiles by the depth of the rebate. Bars are inserted in the direction of the slope of the roof, and the butt hinges used for hanging the sash are invariably fixed as the under side of the top rail.

The joints between the curb and the roofing slates or tiles are made weatherproof with sheet lead. At the upper end—the back of the curb—a small **Lead Gutter** is formed, with the lead going underneath the slates and overlapping the upper edge of the curb. The sides of the curb may be flashed with soakers—short lengths of sheet lead which are worked in between the slates—or the joint may be made with one strip of lead forming a small gutter down the side of the curb. In either case the lead overlaps the upper edge of the curb. At the lower end of the curb, the lead overlaps the slates. To prevent water from rising between the glass and the upper side of the bottom rail, sinkings are cut into the rail. (See Fig. 100).

Dormer Windows. Instead of having the light in or parallel to the plane of the roof, it affords a more artistic treatment of the roof, and often gives a better result in lighting, if the window is fixed vertically. The general arrangement of the framing, as well as of the

sashes, depends upon the kind of roof, the width of the window required, and the general style of architecture of the building.

The construction of a dormer window necessitates trimming of the rafters, and the arrangement of projecting framework, the front of which consists of **Cor-**



Sketch of part of the Roof of a Building, showing a Hinged Skylight and a Dormer Window.

Fig. 100.

ner Posts and **Crossrails**—rebated to receive hinged sashes—which are connected to the main roof by other crossrails and by **Braces.** This framework is surmounted by a **Roof** which may be either ridged, or curved outline, or flat. By arranging a ridged roof to **over-**

hang, and adding suitable **Barge Boards** and **Finial** (Fig. 101) a dormer window may be made to improve the general appearance of the roof of a building. The sides of the dormer may be either boarded and covered with the same kind of material as the roof, or they may be framed for sidelights.

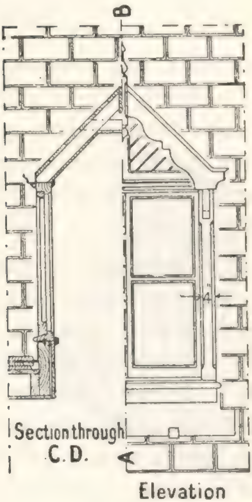


Fig. 101.

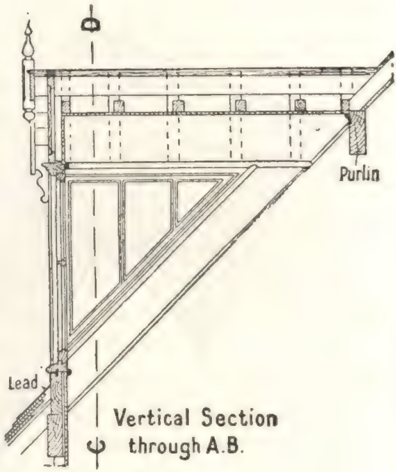
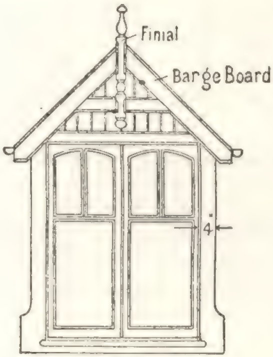


Fig. 102.

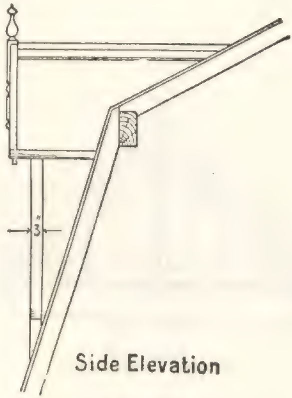
As dormer windows are generally in exposed positions, and the sashes are arranged as casements to open, their efficiency depends largely upon the perfection of the joints between the sashes and the frame. It ought to be mentioned however, that with sashes hung folding, semicircular tongues on their hanging stiles are by far the best. Figs. 101 and 102 give the details of

a dormer window, with sidelights, fixed in a roof of ordinary pitch. The sashes, which are hung folding, open inwards. The roof may be boarded and covered with lead, or it may be covered with slates or tiles. The joints between the roofing slates of the main roof, and the roof and sides of the dormer, are made weatherproof with sheet lead flashings. Figs. 103 and 104 show a dormer window fixed in a Mansard roof; in this example there are no side lights.



Front Elevation

Fig. 103.



Side Elevation

Fig. 104.

Large Skylights and Lantern Lights. For lighting the well of a large staircase, or a room which, for some reason, cannot be lighted with side windows, specially large skylights are often necessary. These are of a more elaborate construction than the skylights already described; they vary considerably in size, shape and design; the plan may be rectangular, polygonal, cir-

cular, or elliptical, and the outline may be pyramidal, conical, or spherical. The framework may be of either wood or iron. To support such a skylight, a strong wooden curb is framed into the roof, and projects from 6 to 9 inches above the roof surface. The joints between the curb and the roof are made watertight with sheet lead. The framework of the skylight may consist of rebated quartering; with separate lights which fit into the rebates of the framing; or the sashes them-

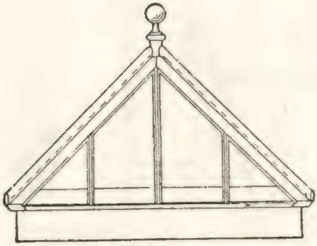


Fig. 105.

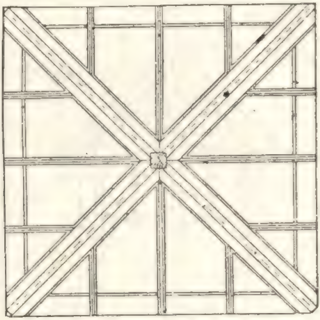


Fig. 106.

selves may be constructed with strong angle stiles, which are mitred together, and provided with either a hardwood tongue inserted in the joint, or with a wooden roll on top to keep out the water.

With skylights of this description, channels for condensed water should always be provided. These are placed at the upper inner edge of the curb, the remainder of the inside face of the curb being covered by either panelled framing or match boarding.

Figs. 105 and 106 give details of a skylight having the form of a square pyramid. In this example the four triangular lights are mitred at the angles, and have wooden rolls over the joints. Figs. 107 and 108 show elevation and part plan of a skylight with a curved roof surface.

A Lantern Light differs from the skylights just described in having, in addition, vertical **Sidelights.** The sidelights consist of sashes, which, by being hinged or

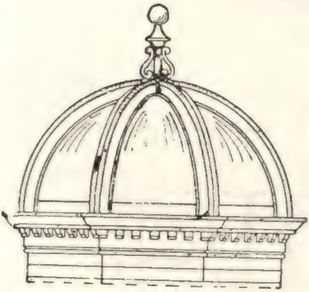


Fig. 107.

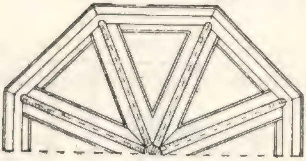


Fig. 108.

pivoted, are often available for ventilation. As they are in exposed positions, the greatest care is required in order to obtain watertight joints. When the sidelights are hinged on the bottom rail, they open inwards; when on the top rail they open outwards. When they are hung on pivots, the pivots are fixed slightly above the middle of the sash. Figs. 109 and 112 show details of a rectangular opening surmounted by a lantern light which is hipped at both ends, and has sidelights arranged to open inwards.

The construction of skylights and lantern lights affords good examples of the application of geometry to practical work as described in previous pages. When

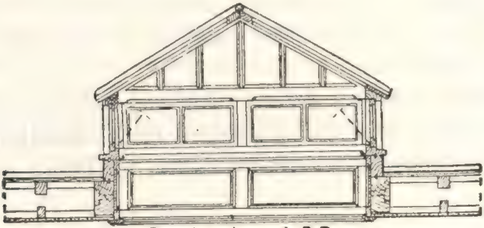


Fig. 109.

the roof-lights are pyramidal as shown in Figs. 106 and 110, and a separate frame is constructed as shown in

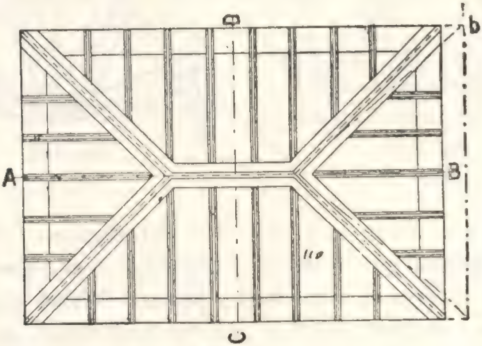


Fig. 110.

Fig. 110, the methods of obtaining the lengths and bevels of the hip rafters are similar to those described for getting hip rafters. When the roof-lights mitre

against one another, the sizes of the lights and the bevels of the angle stiles which mitre together are obtained as shown at X in Fig. 112. With lights of

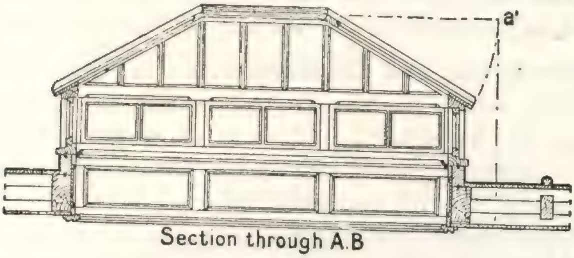


Fig. 111.

curved outline, the shapes of the hip rafters or angle-stiles, as well as the developed surfaces, are obtained as explained before.

Lay-Lights. At the ceiling level of roof-lights used for staircase wells, or in similar positions, it is often

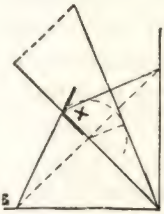


Fig. 112.

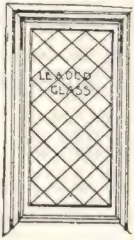


Fig. 113.

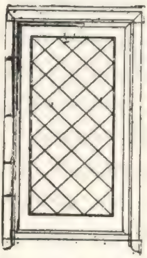


Fig. 114.

considered advisable, for the sake of appearance, to have a horizontal second light called a lay-light. This consists of a sash—or if the space is large, a number of sashes—fixed into frames in the ceiling. The chief

feature of lay-lights is in the attempt at decoration by arranging the bars in some ornamental design (Figs. 113 and 114). The lay-lights are often glazed with ornamental glass, which, although it improves the appearance, diminishes the amount of light transmitted.

Greenhouses and Conservatories. In this type of building which is largely constructed of wood and glass, the framework is usually of moulded and rebated quartering, with side sashes fixed in the rebates. As in the case of skylights, the roof-lights, which in this case reach from the ridge to the eaves, have no crossbars, since these would impede the flow of water running down the slope of the roof. Care should be taken to have the bars strong enough to carry the glass without sagging; and it is well to remember that when a roof is of flat pitch a heavy snowstorm will throw a large additional weight upon it, while with a steep roof the wind has much power. The distance apart of the bars which carry the glass ranges from 12 to 18 inches, and the lengths of the sheets of glass should be as great as possible, so as to diminish the number of cross-joints, since these allow of accumulations of dirt which cannot be removed easily. These roof-lights are constructed in exactly the same manner as skylights; they are, however, often much larger, and require to be thicker, unless purlins are placed to support them. When, as is often the case, part of the roof-light is made to open, this part—often a narrow strip at the highest part of the roof (Fig. 115)—is made as a separate light, which overlaps the upper edge of the fixed lower light. Additional ventilation is secured by arranging the side sashes to open.

The above description is intended merely to outline the broad principles of the construction of conservatories, but it should be remembered that the details, while conforming to casement and roof-light construction generally, lend themselves to considerable variation in design and arrangement.

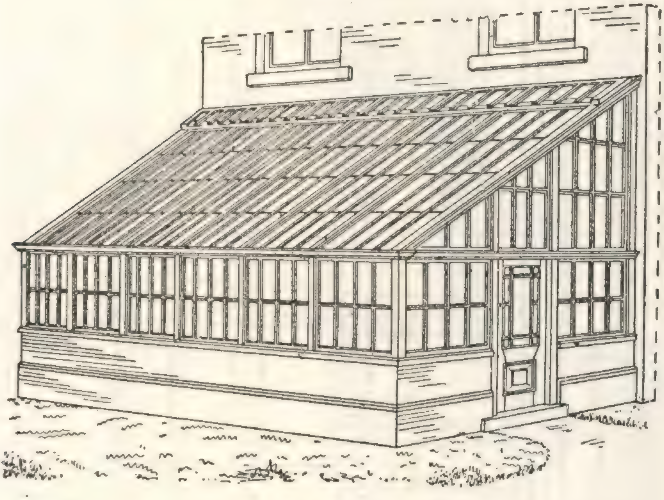


Fig. 115.

A Bay Window with solid frame and casement lights is shown in Fig. 116 to 118. Two methods of fitting such a window, with folding shutters, are given in this plan. In the half plan at C, the shutters fold into a boxing projecting into the room, and at D they fold back upon the face of the wall, which is splayed to receive them. The sills of the frame are mitred at

the angles, the joint cross tongued and fixed with a handrail bolt, which should be painted with red lead before insertion. The joints in the head are halved together, the mullions stub tenoned and fixed with

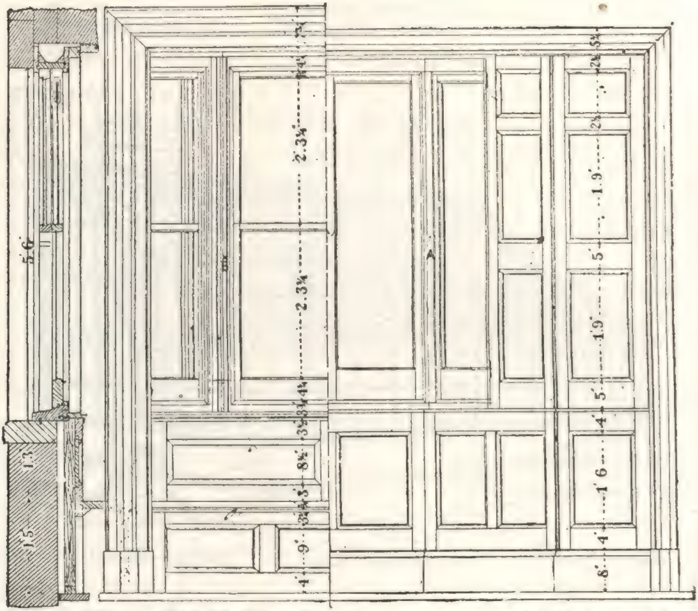
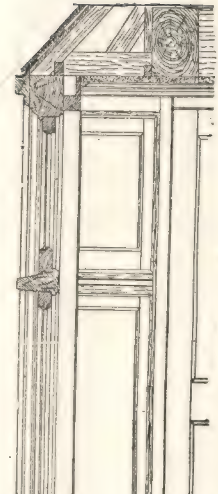


Fig. 116.

coach screws. The jambs are tenoned and wedged into the head and sill. The transom tenoned into the jambs and mullions, and secured with bolts. The mullions may be worked in one piece as shown at D, or built up as at C, and tongued and screwed together.



Section on A_B

Fig. 117.

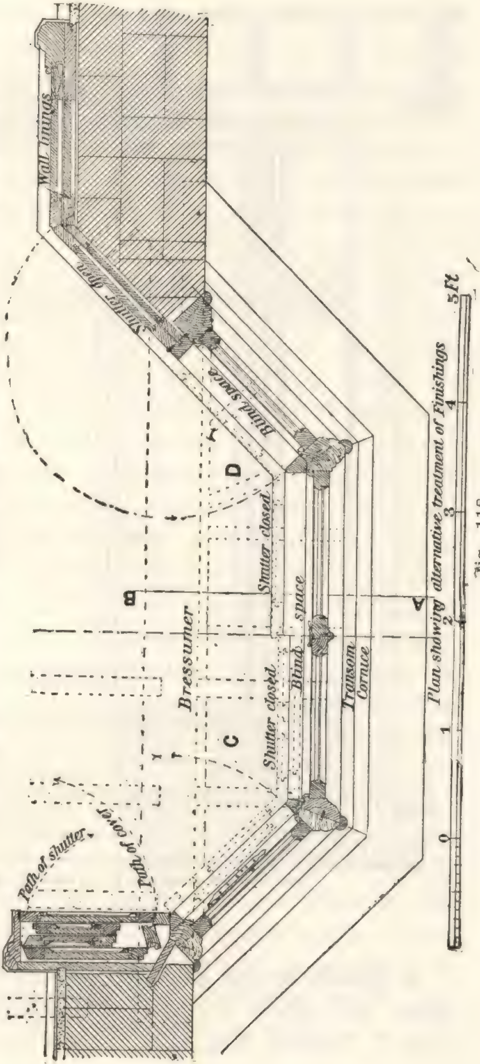


Fig. 118.

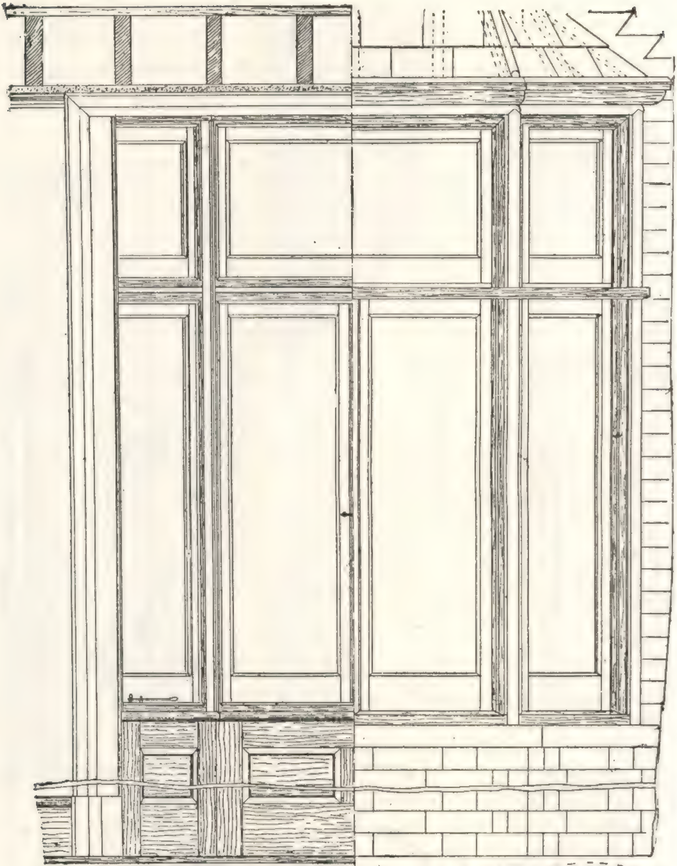


Fig. 119.

A Cased Frame Bay Window is shown in the half plan, half inside elevation, and central vertical section, Nos. 1, 2 and 3, Fig. 119. This window is composed of

three ordinary sash frames, the sills connected at the angles either by halving and screwing or by mitreing them and fastening the joint with a hand rail bolt. The heads are tied together with a short piece of 1 in. stuff screwed across the top of the joints, and the joints in the linings are covered by the mullions of the blind frame B. The latter, made 2 in. wide, forms an enclosure for venetian blinds. Boxings are formed in the elbows between the sash frames and the interior face of the wall, the front of the opening being finished off with a moulded ground and architrave. These form receptacles for the folding shutters, which are curved in plan, and when opened out convert the octagonal bay into a segmental niche. The window back and the seat beneath are also curved to parallel sweeps. The window board also follows the sweep, and is rebated to receive the shutters, a shaped bead being fixed on the soffit to form a stop at the top. Nos. 4, 5 and 6 on the same plate illustrate another method of finishing a bay window. In this case the frame is solid, and is fitted with outward opening casement lights. A blind frame is provided, and the shutters fold on to the face of the jamb and wall, the outer edges passing behind the rebated edges of the architrave; the latter is continued down to the floor, and elbow linings to correspond with the shutters are fitted beneath the window board. These are fitted to the window back in the manner indicated by the dotted lines in the plan No. 4. The section No. 6 shows the treatment of the roof of the bay, which is segmental in section and covered with shaped pan-tiles. The ribs, which are elliptic at the hips, are notched into a wall plate rest-

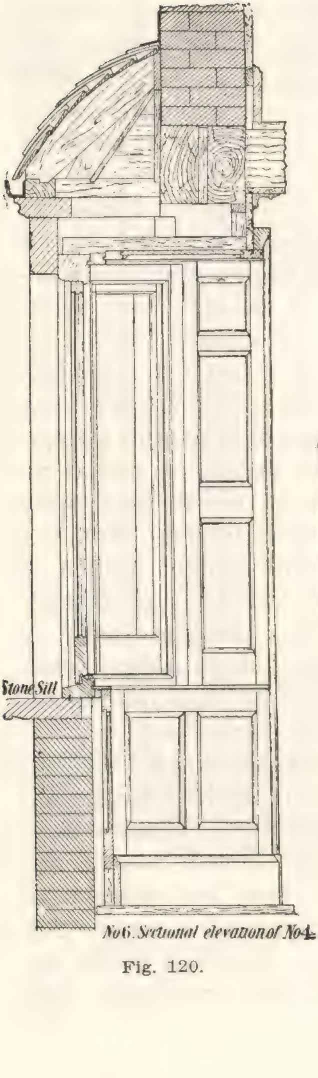


Fig. 120.

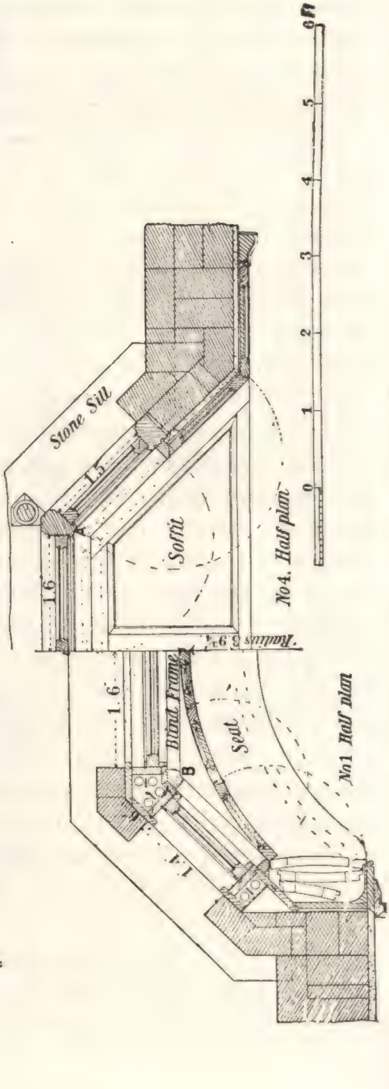


Fig. 121.

ing on the stone cornice, and are nailed at the top into a shaped rib fixed on the face of the wall; the ribs are covered with weather boarding, which affords a good fixing for the tiles. The wall is carried by a breast. summer formed of two 12 in. by 6 in. balks bolted together, with spacing fillets between, and the soffit is carried by three brackets fixed to the breastsummer and the head of the window frame.

A Pivoted Light in a solid frame is shown in elevation in Fig. 122 and section Fig. 123. These are used chiefly in warehouses, lanterns, and other inaccessible positions, the lights being opened and closed either by cords and pulleys or by metal gearing. For small lights the frames are usually made out of 4½ in. stuff by 2 or 3 in. wide. Small lights are pivoted horizontally, large ones vertically. The pivot should be fixed to the frame, not the sash, and from ½ in. to 1½ in. above the centre, according to the weight of the bottom rail. The lower part of the sash should exceed in weight the upper part, just sufficient to keep it closed; its action may be easily demonstrated by inserting two bradawls in the stiles, and balancing them on the fingers. The sash is inserted and removed from the frame either by means of plough grooves in the edges of the stiles, as shown by the dotted lines in Fig. 122, or by cutting a notch through the face of the stile for the passage of the pin, which is concealed when in use by the guard beads. This latter is the better method, as it does not reduce the strength of the sash, as does the former, by cutting away the wedging. The stop beads at the sides are cut in two, one part being fixed to the frame, the other to the sash. Their joints can be at any angle

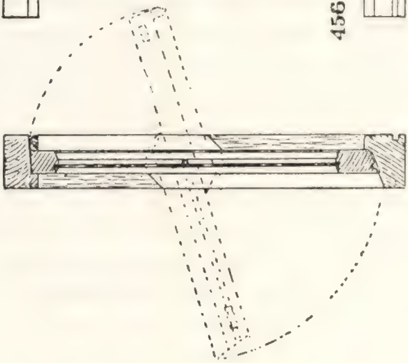


Fig. 122.

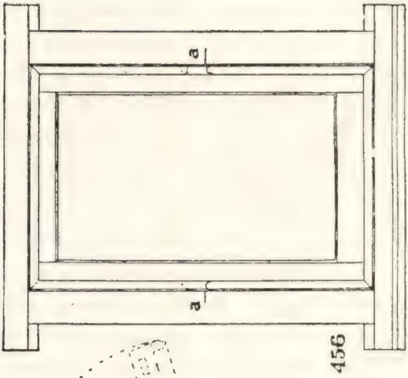


Fig. 123.

Elevation and Section of a Pivot Hung Sash.

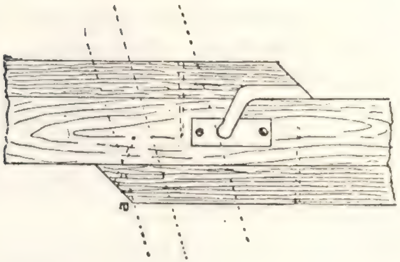


Fig. 124.

Method of Finding Cuts in Bead

greater than that made by a line tangent to the sweep at the point of intersection a Fig. 124, but for the purpose of using the Mitre Block, they are generally made at an angle of 45 deg. A curved joint has no advantage over a straight one, except in being more expensive.

To Hang the Sash. Insert the pivots in the frame quite level, but do not screw them. Then with the try square resting on the top of the pins, square lines across the jambs. Then remove the pivots and insert the sash, which should be fitted rather tightly at first, and square the lines on to the sash. Return these on the edges, and keep the edge of the hole in the socket plate to the line, and the plate itself in the middle of the thickness. After the socket is sunk in, and the notches cut, test the sash and correct the joints, which should be a bare 1/8 in. clear all round.

To Find the Position to Cut the Beads. After fitting them round, remove them and open the sash to the desired angle, which should be less than a right angle, so that the water may be thrown off. Lay the beads upon the sash upside down for convenience of marking, and draw a line along their edge upon the jambs at the point where the line meets the faces of the frame; square over lines as at a a Fig. 123; the position is shown in Fig. 122, the outer dotted lines indicating the beads. Next replace the beads and transfer the marks to them, cutting them off the mitre block (remember that the mark is the longest point of the mitre). The upper portions outside and the lower inside are fixed to the frame, and these are shaded in the drawings. The remainder of the beads are fixed to the sash.

The above describes the method when the sash is grooved. Where the beads are slotted, a variation must be made with reference to the top cut (see Fig.

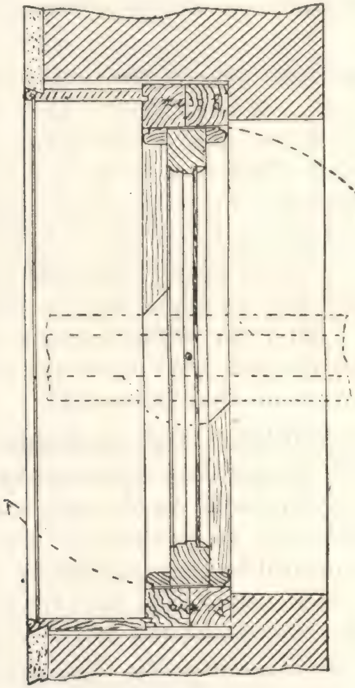


Fig. 125.

124). In this case the sash must be drawn out and rested upon the pin, then the bead laid on it and marked as before, the intersection a giving the mitre point.

A Bull's-Eye Frame with a pivoted sash is shown in Figs. 125 and 126 and enlarged detail of the joint. This frame is built up in two thicknesses, glued and screwed together, each ring being in three pieces breaking joint. The beads may be steamed and bent round, or worked on the edge of a board that has been cut to the sweep,

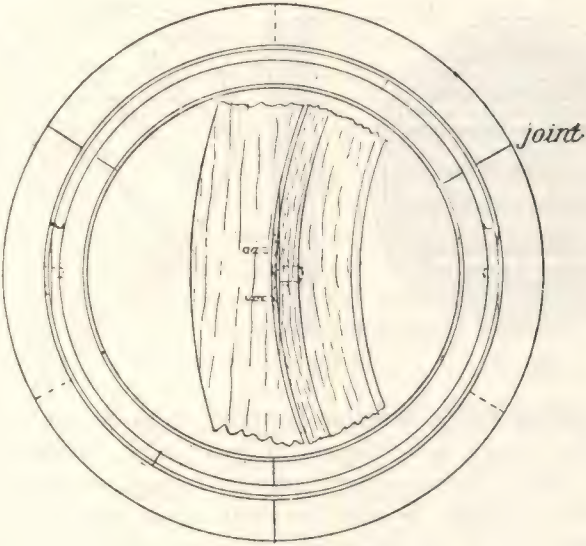


Fig. 126.

and cut off in two lengths. The sash is made in three pieces, with butt radial joints bolted together. To enable the sash to open, a plane surface must be provided at the centre, equal to the thickness of the sash and beads, as shown by the dotted lines. Having fitted the sash in, and the beads around each side, brad them tem-

porarily to the sash, lay a straight-edge across it parallel with the centre, and square up with the set square a line at each side equal in length to the thickness, then cut the pieces so marked off with a fine saw, both beads and sash, and glue them to the centre of the frame, and fix the pivots to these frames and proceed as in a square frame.

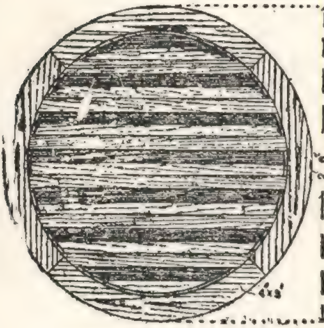


Fig. 127.

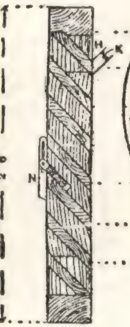


Fig. 128.

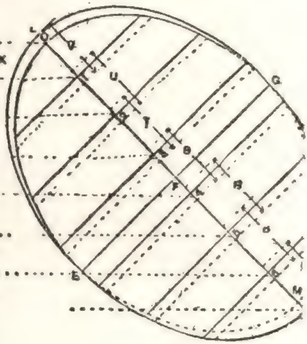


Fig. 129.

Laying Out a Circular Louvre: Suppose the frame of the louvre to be formed of four pieces, as shown at Fig. 127. These sections may be formed of one thick piece of plank, or may be built up of several thicknesses. If of one thickness, the joints may be held together with handrail screws, or dowelled and keyed. If of several thicknesses then the joints can be broken or overlapped, and the pieces either screwed or nailed together. To set out the louvre boards, make a sketch of the whole thing, full size, as shown at Fig. 127, then set up the section or side as shown at Fig. 128, then project from the quick of the bead, then draw a line C D, Fig. 129, parallel to the inclination of bevel of

the louvre boards. This will give the major axis of an ellipse. Bisect this line and draw E, F, G, at right angles to C, D, making E, F, and F G each, equal to half the radius from the centre of the frame to the quick of the bead. The ellipse C, E, D, G, may be struck by any of the methods shown. As, of course, all the louvre boards are at one angle, each forms a portion of the same ellipse. From the centre of the front edge of each louvre board, project across to the major axis as shown. Now from any of the louvre boards set off, at right angles, lines from the upper and lower surfaces as shown at H, Fig. 128, then the distance K, is the amount of projection of the lower surface in front of the upper. Taking half the distance of K, measure it off on each side of the centres 1, 2, 3, 4, 5, 6. Fig. 129, then through the points last obtained draw lines parallel with the minor axis, the upper line representing the top front board or arris of the boards, and the dotted line the bottom arris. Now measure the distances K, from C to L, and from D to M, and construct the ellipse for the underside of the boards. The following will be found a simple method for making out each louvre board: Cut a thin mould equal to one-quarter of the ellipse, the edges of the louvre boards having been planed to proper bevel, as shown at N, Fig. 128, square the centre line across the piece that has to form the louvre board and lay it on the setting out at Fig. 129, the centre line of course corresponding with C D. The quarter mould which was prepared can now be laid on the louvre board, with its curve standing directly over the development, Fig. 129, the face side of the material being of course the side marked out.

The curves for the underside may be marked off on the arrises direct from the development, and the mould then applied to the other side, taking care to adjust it in the right position and to the marks made. The ends should be sawed and turned to the lines. The next proceeding will be to set out the frame for the grooves; these are represented in the conventional sketches, 4, 5 and 6. It will be noticed from Fig. 132 that the bottom louvre board is not grooved in all round; this is a bet-

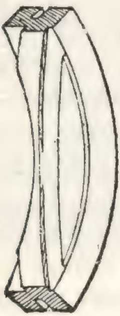


Fig. 130.

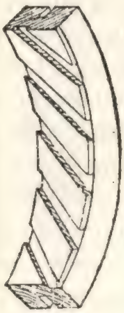


Fig. 131.

Fig. 132.

ter method than bringing it out to the front and thus destroying a part of the margin bead of the frame. The cutting of the grooves and the fitting in of the louvre boards requires careful working in order to get good joints. It must be clearly understood that Fig. 129 is not a full development of all the boards edge to edge, as that could not be represented in this space, but enough is shown to give a clear idea of how the lines are obtained. The full breadth of each is represented by the dimension lines O, P, R, S, T, U, V, and from this all the other is easy.

The Construction of Doors. **Doors** are named in accordance with their modes of construction, position, style or the general arrangement of their parts, and also the method in which they are hung, as **Battened,**

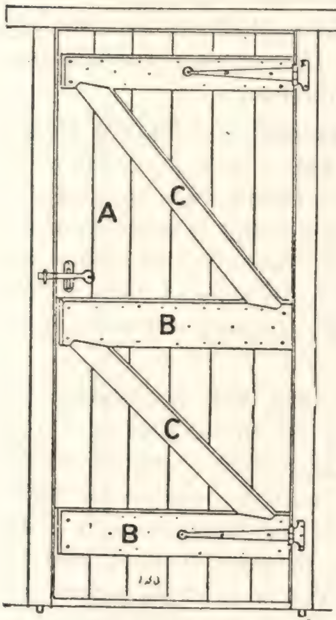


Fig. 133.

Fig. 134.

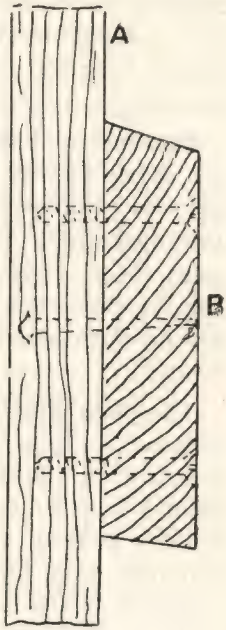


Fig. 135.

Battened Framed and Braced, Panelled or Framed, Entrance, Vestibule, Screen, Sash, Diminished Stile, Double Margin, Gothic, Dwarf, Folding, Swing, Jib, Warehouse Hung, &c. The essentials in the design and construction of doors are, for the first, that they shall have a due proportion to the building or place they

have to occupy and be suitably ornamented; in the second, that their surfaces shall remain true and their parts be so arranged and connected that their shape will be unalterable by the strains of usage and the effects of weather. The various examples illustrated will indicate the points to be considered in designing doors for sundry situations, and the methods of construction herein described will supply the necessary information to meet the constructive requirements.

Battened and **Battened Framed** and **Braced Doors** are shown in Figs. 133 and 134. These doors are suitable for positions where one or both sides are exposed to the weather. Little or no attempt is made to ornament them—economy of cost, strength and utility being the chief requirements of this class of door, which are fitted to coach-houses, W. C.'s and outhouses generally.

The plain **Battened Door** (Fig. 133) is composed of battens A, from ¾ to 1¼ in. thick, ploughed and tongued in the joints with straight tongues which should be painted before insertion, nailed to three ledges, B from 1 in. to 1¼ in. thick, usually with wrought nails long enough to come through and be clinched on the back side. The ends of the ledges are better fixed with screws, and their top edges as well as those of the braces C should be bevelled to throw off the water, as shown in the detail, Fig. 135. The lower edges may be throated or bevelled under, as shown The braces should be placed so that their lower ends are at the hanging side, for if in the opposite direction, they will be useless to prevent the door racking. Their ends should be notched into the ledges about 1 in.

deep and $1\frac{1}{2}$ in. from the ends, with the abutment square to the pitch of the brace. Narrow doors are sometimes made without braces, but they seldom keep "square." These doors are hung with wrought-iron strap hinges called cross garnets, which should be fixed on or opposite the battens, whether placed on the face or back of the door.

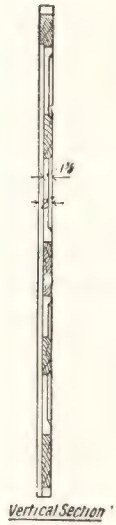


Fig. 136.

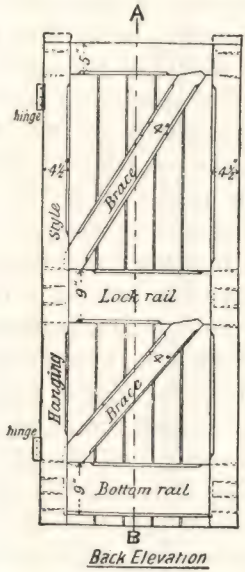


Fig. 137.

The Framed Battened and Braced Door (Figs. 136 to 137) differs from the former in that the battens and ledges are enclosed on three sides by a frame of a thickness equal to the combined thickness of the battens and ledges, so that it is flush on each side with

them. The boards are tongued into the frame at the top and sides, and the ledges are framed into the stiles with barefaced tenons. The braces should not be taken into the angle formed by the stile and rail, but be kept back from the shoulder about 1 in., as shown. If the brace is placed in the corner, the strain thrown on it has a tendency to force off the shoulder, unless the door is very narrow, when the brace will be nearly upright. These doors, as in fact all framed work exposed to damp, should be put together with a quick drying paint instead of glue in the joints, because ordinary glue has such an affinity for water that it will soften in damp situations releasing its hold, and also be the means of setting up dry-rot in the timber. The battens in these doors should be made 1/16 in. slack for each foot of width to allow for subsequent expansion, or otherwise the shoulder will be forced off. The framework of these doors is first made and wedges up, then the battens folded in and driven up into the top rail and nailed to the ledges, after which the braces are cut tightly in and nailed to the battens in turn, and the whole cleaned off together. In large gates of this description it is usual to stub tenon the braces into the rails, in which case they must be inserted first and wedges up with the framing.

Framed or **Panelled Doors** are of several kinds, distinguished by the number or treatment of their panels, or by the arrangement of the mouldings, as follows:

Two to Twelve Panel Doors.

Square and Sunk. When a thin panel is used without mouldings, as shown at A in the elevation diagram of a **Framed** or four-panel door (Fig. 138).

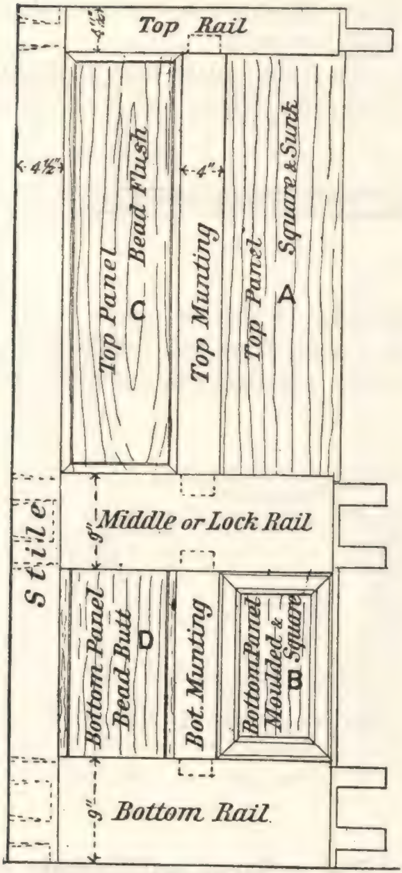


Fig. 138.

Fig. 139.

Moulded and Square. When one side of the panel is moulded and the other plain, as at B.

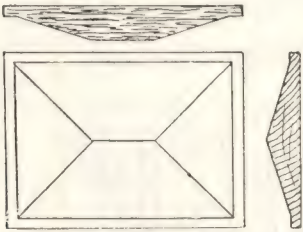
Bead Flush. When one side of the panel is flush, or nearly so, with the frame, and with a bead worked round the edges to break the joints, as at C.

Bead Butt. When the bead is worked only on the two sides of the panel, as at D.

Raised Panel. When the centre part of the panel is thicker than the margin. There are four varieties of raised panels:

Fig. 140.

1. **The Chamfered.** In this the panel is chamfered down equally all round, from the centre to the edge when square, or from a central ridge if rectangular, as shown.



Plan and Sections of a Chamfered Raised Panel.

Fig. 142. Fig. 141.

2. **Raised and Flat** or **Raised and Fielded.** When a chamfer is worked all round the edge, leaving a flat in the centre, as at A, Fig. 142.

3. **Raised, Sunk and Fielded** (as at B, Fig. 142). When the chamfer starts from a marginal sinking below the face.

4. **Raised, Sunk and Moulded** (as at C, Fig. 143). When the edge of the sinking is moulded.

Stop Chamfered. When the edges of the framing are chamfered and stopped near the shoulders.

Bolection Moulded. When the panel moulding stands above, and is rebated over the edges of the framing, as shown at Fig. 142.

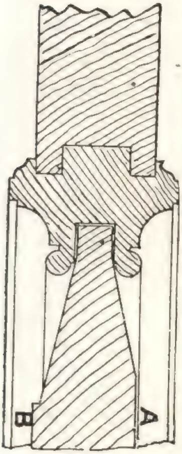


Fig. 143.

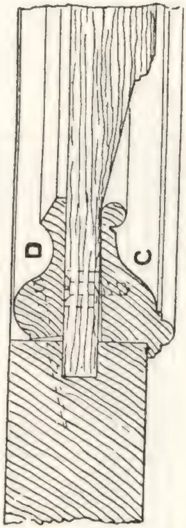


Fig. 143½.

Double Bolection Moulded. When the moulding on each side of the door is made in one solid piece, grooved to receive the panel, and is itself grooved and tongued into the framing. This variety is shown at Fig. 142.

Constructive Memoranda. The outside vertical members of doors (in common with all framed work) are

called stiles. The one the hinges are fixed to is called the hanging stile, the one containing the lock the striking stile. In a pair of doors the two coming together are called the meeting stiles. The inside vertical members are the mountings, or more commonly muntings. The horizontal members are rails, respectively, top, frieze, middle, or lock, and bottom. The panels are

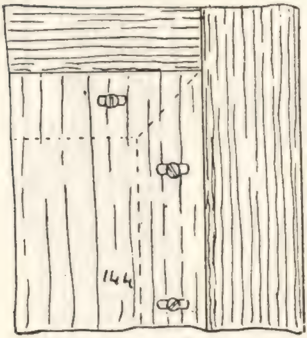


Fig. 144.

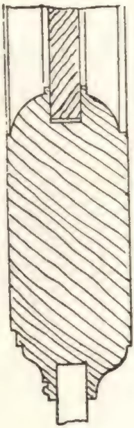


Fig. 145.

named similarly. When the grain of these run horizontally, they are said to be "laying" panels; when vertically, "upright." Doors are called **Solid-Moulded** when the moulding is wrought or "stuck" in the substance of the framing itself, as is shown at Fig. 145; and **Planted** when the moulding is worked separately and bradded around the frame, as shown at a, Fig. 143, and D, Fig. $143\frac{1}{2}$. These are also called sunk mouldings.

Bead Flush Panels are commonly made as shown at a, Fig. 146, but such panels will, unless made of thoroughly seasoned stuff, inevitably split when drying. The correct way to obtain the effect of bead flush panelling is to work the beads upon the edges of the framing, as shown in Figs. 147 and 148.

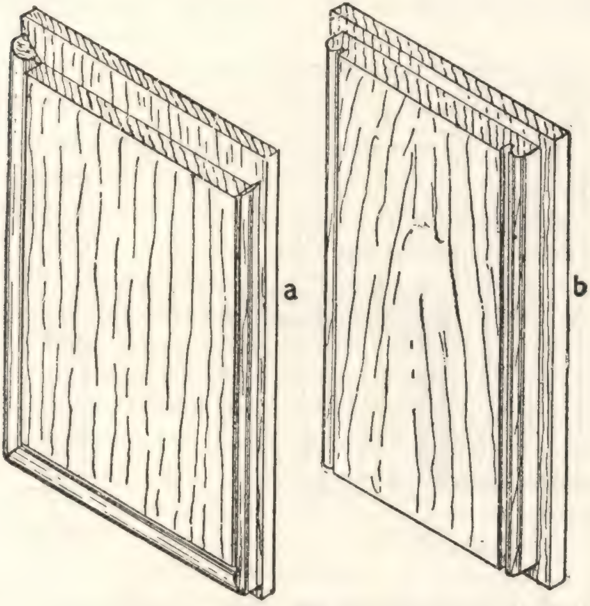


Fig. 146.

Bead Butt Panels are better kept about 1/32 in. below the framing, as a truly flush surface is difficult to prepare through the yielding of the panel, and when produced, will seldom last, as the shrinkage of the panel and frame is unequal. Planted-in "sunk" mould-

ings should be fixed to the framing, not to the panels, as shown in Fig. 143, D; for if fixed to the panels, when the latter shrinks the moulding will be drawn away from the frame, leaving an unsightly gap. The back edge of the moulding should be bevelled under as shown, so that when bradded in, the front edge will keep close down to the panel. As it is not permissible

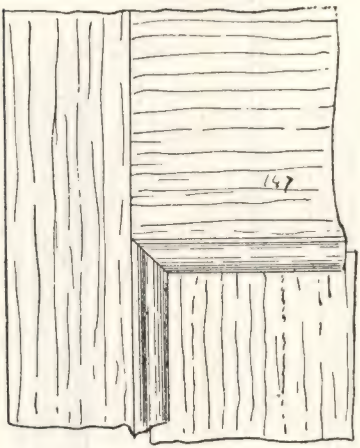


Fig. 147.

Fig. 148.

to brad polished mouldings, except in the case of inferior work, these are usually glued to the frame, and their back edges should of course be square. The panel should be polished before the moulding is planted in, so that in case of shrinkage a white margin will not be shown. When, however, the moulding is wide and thin, it is unavoidable that it be fixed to the panel to keep its front edge down, and to overcome the diffi-

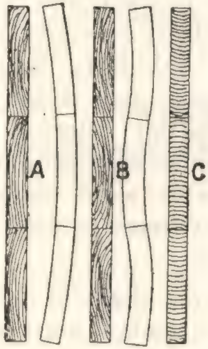
culty of shrinkage. The stiles in vertical and the rails in laying panels are prepared with a second shallow groove as shown, and the moulding, made with an extra wide quirk, is cut in and pressed back into the groove. It is glued to the panel, and shrinks with it without showing a gap. The cross pieces across the ends of the panel have their quirks shot off to the proper width, and are sprung in after the side pieces are in place. These are dowelled but are not glued, or when there is a moulding at the back, the face side is slot screwed.

Bolection Mouldings are intended to be fixed to the panels, which is rendered necessary by their great width and thickness, and they are rebated over the edge of the framing to prevent the interstices produced by the shrinkage showing. From 1/8 to 3/16 in. is sufficient for this purpose, and more should not be given or the edge will be liable to curl off. To prevent the panel being split by the fastenings when it shrinks, the moulding is fixed by slot screws, as shown in Fig. 143, the slots being cut across the grain. See the back view, Fig. 144. The moulding should also be screwed together at the mitres, and the latter may be grooved and tongued with advantage, and dropped into the panel as a complete frame, where it is fixed as described, the heads of the screws being covered by the interior moulding, which, if a sunk one, is glued to the frame, and if a bolection, dowelled to the panel, or, as is sometimes done in inferior work, bradded, and the holes filled up with colored stopping. It is not good construction to glue the moulding to the panels in any case, as the alteration of size in the latter, due to the state of the atmosphere, is very liable to cause them to

split, if fixed immovably, or when swelling, to disarrange the mitres. The bradding in of mouldings is less likely to do this if the brads are not placed too thickly, as they yield slightly to the pressure. Framing is usually grooved ½ in. deep for the panels, and the latter given ⅛ in. play sideways, but fitting close lengthways of the grain. This is sufficient for panels up to 2 ft. wide. Over that width the grooves should be ⅝ in. deep, and the panel enter ½ in. at each side. Ordinary dry stuff will eventually shrink about ⅛ in. to the foot, and will swell equally if exposed to damp. When wide panels are used they will warp less if glued up in several pieces, as the pull of the fibres is lessened by the cutting, and the effect of the warping is diminished in the same ratio as their width. Much can be done to ensure the permanent flatness of panels by paying attention to the way the boards have been cut from the tree. The direction of the annual rings on the end will indicate this, and the various pieces should have their similar sides placed together. What is meant by this will be rendered plain by an examination of Fig. 149. When a panel is glued up with the hollow or heart sides of the rings all on one face as at A, and the board warps, it will case in one continuous curve, as shown in the unshaded diagram, whilst if glued up with the heart sides reversed alternately, as shown at B, it will assume the serpentine shape shown in the unshaded diagram. Boards cut radically or with the annual rings perpendicular to the surfaces, as at C, will swell less than the others, and will not warp perceptibly.

Proportions. The size of doors depends so much upon the scale and design of the buildings they occupy, that

no definite data can be given, within reasonable limits, for important doors; but it may be pointed out that very large doors not only tend to dwarf a building or a room, but they also take up a great deal of space in opening, and the difficulty of preserving their accurate fitting increases in direct ratio with the size. The following may be taken as an indication of the more usual dimensions given to ordinary good class dwelling house doors: **Entrance Docrs**, from 7 ft. to 8 ft. 6 in.



illustrating the Effect of Position on the Parts of a Panel.

Fig. 149.

high by from 3 ft. to 4 ft. 6 in. wide, 2 to 2½ in. thick. **Reception Rooms**, 7 ft. by 3 ft. 3 in. by 2 in. **Bed-Rooms**, 6 ft. 8 in. by 2 ft. 8 in. by 1½ in. Details of interior doors; stiles and top rails, in common work, out of 4½ in., muntings and frieze rails 4 in., middle and bottom rails 9 in. Superior doors vary much, but gen-

erally stiles and rails are somewhat wider than the above, muntings and frieze rails narrower. Height of lock rail usually 2 ft. 8 in. to its centre. This is a convenient height for the handle, which is generally placed in the middle of depth of rail. When an entrance door is approached from a step the middle rail is kept about 6 in. lower, to bring the height of the handle convenient.

Common Doors, both internal and external, are made of "yellow pine" or Georgia pine throughout. A better class of interior doors have yellow pine frames and white pine panels. The latter wood should not be used for external work, as it is far too soft and will not stand wet. **Superior Internal Doors** are made throughout of Honduras mahogany, black walnut and oak; also of pine and baywood, veneered with Spanish mahogany. **External Doors** of oak, teak, walnut and pitch pine.

In constructing doors of any of the above mentioned figure woods, great attention must be paid to the arrangement of the members, so as to balance the figure, and this may also well be studied in the conversion of the plank. For instance, two stiles, each having pronounced figure at one end, and the other end plain, should have the figured ends placed at the bottom. This gives the effect of solidity, whilst the reverse would make the door look top heavy. Similarly the upper rails should be plain, the lower figured. It must be understood the above only applies when the wood is a mixed lot. When the wood is handsomely figured throughout, the point of most importance is the effect of its position upon the figure, and this is so great that

in some of the light-colored woods, wainscot and baywood for instance, a piece that in one position will appear richly figured will in another show quite plain and dull. The best way to judge the effect is to prop the pieces up in the approximate positions they will occupy when finished, facing a top light. Then when standing a few feet off, the play of light on the fibres will be observed. Deep-colored woods, such as teak and Spanish mahogany, may have their figure brought out by slightly oiling them, which will facilitate their arrangement. Panels also require balancing, the more

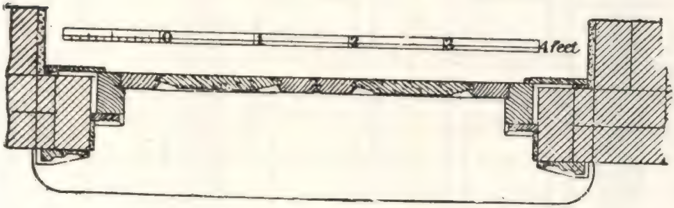


Fig. 150.

heavily marked ones being placed below plainer ones, and symmetrically arranged, either in pairs, or figured in the centre and plain outside. In all cases where the figure is coarse, taking a truncated elliptic shape, the base or wider part should be kept downwards. The panel at B is upside down from an artistic point of view. This arrangement is known in the workshop as "placing the butts down," although as a matter of fact the width of the figure is not due to its being towards the butt end of the tree, but merely to the accidental position the surface of the board occupies with relation to the annual rings, which are more or less

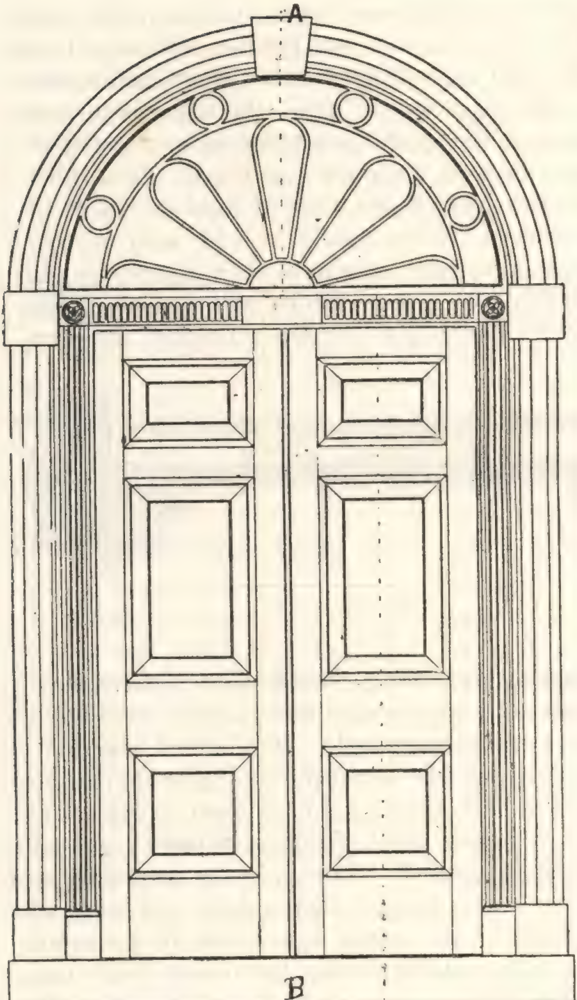


Fig. 151.

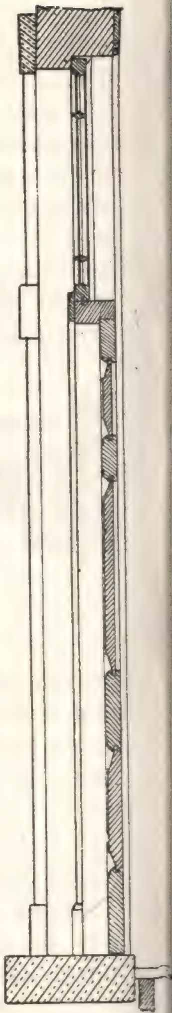


Fig. 152.

waved in length, due to crooked growth, and the board passing through them in a plane, their edges crop out on the surface in irregular elliptic shape.

Double Margined Doors are wide single doors framed to appear as pairs of doors. They are used in openings too wide proportionately for a single door, but where half the opening would be rather small for convenient passage. Figs. 150 to 154 show elevation and sections of a **Double Margined Entrance Door**, typical of the style in vogue in the latter part of the eighteenth and early part of the nineteenth centuries.

These doors are made in two ways. In the earlier method the central imitation stile, which in this case is really a munting, is made in one piece and forked over the top and bottom rails, which are continuous. The intermediate rails are stubtenoned to the central, and through tenoned and wedged to the outside stiles, but unless the stub tenons are fox-wedged, the shoulders are very liable to start, for which reason the method of construction now to be described is generally preferred. The door is composed of two separate pieces of framing, each complete with two stiles and a set of rails that are tenoned through and wedged up. The two portions are then united by a ploughed and tongued and glued joint, which is hidden by a sunk bead in the centre, as shown in the diagram, Fig. 155, and the parts keyed together with three pairs of hardwood folding wedges. The door is sometimes further strengthened by having flat iron bars sunk and screwed into the top and bottom edges. The actual process of putting the door together is as follows: After the various rails and panels have been duly fitted and marked,

each leaf is taken separately and the stiles knocked on. The one intended for the meeting stile having been

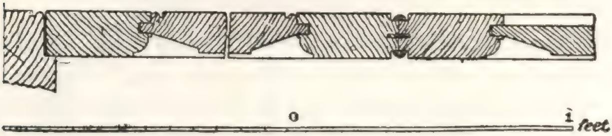


Fig. 153.

Fig. 154.

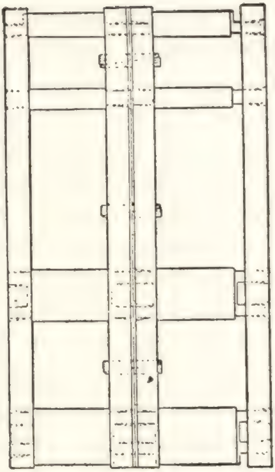


Fig. 155.

Fig. 156.

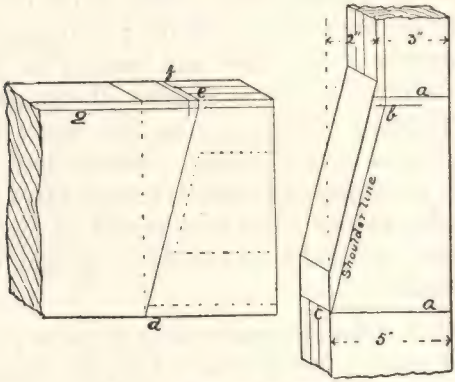
glued, is cramped up and wedged. Then the meeting stiles are made to a width, grooved, jointed, and re-

bated for the beads, as shown in the detail, Fig. 150. The ends of the tenons and wedges should be cut back ⅛ in. to prevent them breaking the joint when the stile shrinks. The mortises for the keys will have been made when the mortises for the rails were done, and cross-tongues are next glued in, the joint rubbed, the two stiles pinched together with handscrews, and the oak keys, well glued, driven in. At this stage the frames are stood aside to dry, after which the projecting ends of the keys are cut off, the panels inserted, and the two outside stiles glued and wedged in the usual manner. After the door is cleaned off, the grooves to receive the beads are brought to their exact size with side rabbit and router planes. Should iron bars be used, they are inserted in grooves made after the door has been shot to size. The bars should be about ½ in. shorter than the width of the door, so that the ends are not visible.

Diminished stiles are sometimes cut out in pairs from a board or plank. When this is done, the back or outside edge is shot straight and the setting out made thereon, the two portions being gauged to width also from the back, but the method more suitable for machine working. Here the stile may be cut parallel to the full width, the face edge shot in the usual way and the setting out made upon that, the diminish being gauged from inside. In this method the mortises are made before the diminished part is cut out, to render that operation easier for the machinist. He should not, however, mortise right up to the sight lines on the diminished part, because if the chisel is at all out of upright when the waste is cut away, the mortise will be

found beyond the sight line, which will be a serious defect.

To Set Out the bevelled shoulders of the stile and rail. Taking the stile first, having as described in the first method gauged and faced up the inside edges, and set out the width of the rails and mortises on the back edge, square over on each side the sight lines of the middle rail as at a a, Fig. 156. Then draw a second

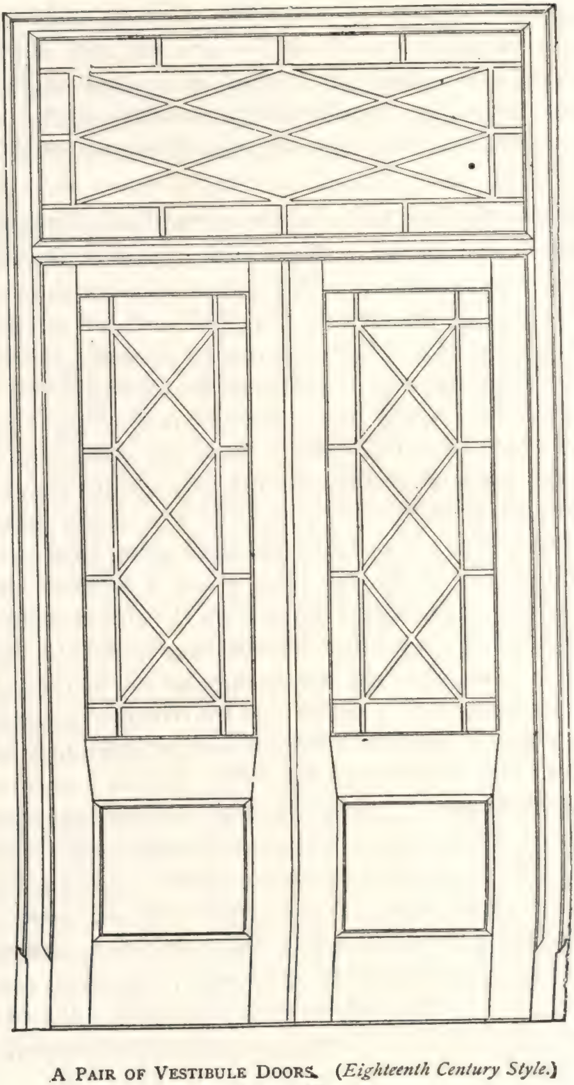


Stile and Rail of a Diminished Stile Door.
Method of Obtaining Shoulder Lines.
Fig. 156½.

line representing the depth of sticking of the rail on the face side, and the rebate on the back side, as at b. Next run gauge lines down on each side of the diminished part as working lines of rebate and sticking, and from the points of intersections of the stickings and rebates respectively, draw in the shoulder lines to the sight line of the lower edge of the rail at c. The only difference to be made when the stile is prepared by

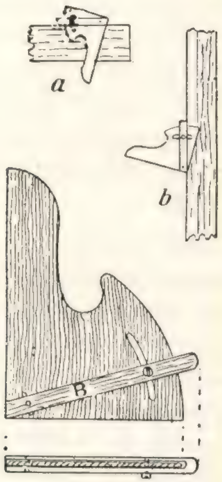
the second method is that the sticking and rebate gauges would be run from the original face edge instead of the actual diminished edge, and as before stated, the sight lines would be marked on the face edge instead of the back, and squared down to the intersections.

To Set Out the Rail. Mark on the bottom edge the "width" or sight lines of the widest part of the stiles. Square this point on to the upper edge as shown by dotted line in the sketch, Fig. 156, and set off therefrom the amount of the diminish on the stile, as shown by the dotted line on the stile in the example: this is 2 in. This line, knifed in on the edge, is the "sight line" of the upper part of the stile. Again set off beyond this line the amount of the sticking and rebate shown in the sketch by the lines e and f. Next run the sticking and rebate gauges on front and back sides, as shown at g; and square down the lines e and f to meet them. Then draw the shoulder lines from the intersections to the point d on each side. Having thus found the shoulder line upon one rail, bevels may be set to them and used to mark any number. A contrivance sometimes used when a large number of similar shoulders have to be set out is shown in Fig. 157. This is known as a **Shoulder Square.** It consists of an ordinary set square provided with a movable fence or bar B, which is slotted to pass on both sides of the square, and is pivoted near the right angle. A set screw near the outer end of the bar passes through a concentric slot, and fixes the fence in any desired position. The pivot works tightly in a small slot to allow the lower edge of the bar to enter the right angle, and the outer edge of the



A Pair of Vestibule Doors. (*Eighteenth Century Style.*)
Fig. 157.

square is also made a concentric curve to permit the easy passage of the end of the bar. The theory upon which the action of the tool is based is that the angle between the parallel bar B and either of the edges of the square is the complement of the remaining angle, the two combined forming a right angle which is the



An Adjustable Square
for Bevel Shoulders.

Fig. 157½.

desired angle between the edges of a rail and stile. Its application is shown in the upper part of the figure, a being the rail, b the stile. Either a rail or stile is first set out as described above, the edge of the square set to the shoulder line, and the bar brought up to the face of the work and fixed with the set screw when it

is ready for application to the other piece. The moulding upon a diminished stile should not be mitred but continued on to the shoulder, and the rail scribed over it, which will prevent an open joint occurring should the rail shrink. When doors, after knocking together, are stored for a second season, a slight difference will have to be made in the setting out of the shoulders of the middle rail. The wider part of the stile will shrink more than the narrow part, and consequently if the shoulders are set out accurately at first as described above, when they are refitted the shoulders will be found short at the lower ends. To prevent this, allow about 1/32 in. extra on the lower part of the shoulder at each end of the rail.

A Gothic Door of the Tudor period is shown in the elevation in Fig. 158 and section in Fig. 159. The head is four-centred. The upper panels are pierced tracery, and the lower ones carved drapery. The mouldings in this type of door are invariably stuck solid, and those on the stiles stopped at the sight lines of the rails. The mouldings on the latter are also frequently stopped at the muntings as shown especially in the earlier work. Many of the doors, however, of the Tudor period have the upper ends of the muntings mitred. In modern work of this style, when the mouldings are not stopped, it is usual to scribe them at the intersection. Chamfers, however, are always stopped to obtain a square-built shoulder for the munting, as a shoulder scribed over a chamfer soon gets faulty through the shrinkage.

Mediaeval doors were always constructed of oak, but **pitch** or **Georgia pine** is now much used in this

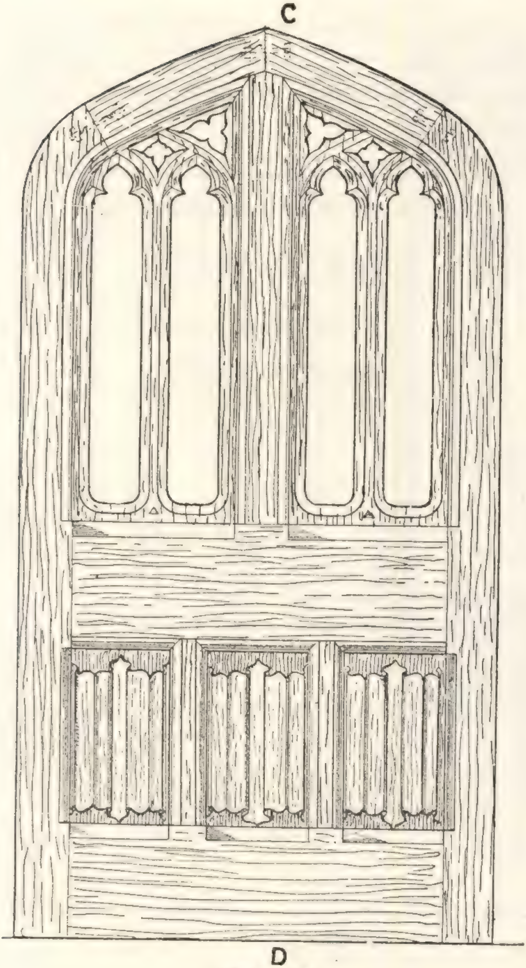


Fig. 158.

Fig. 159.

style of work. The older examples are mortised, tenoned. and pinned together, wedging and glueing being a modern invention. The joints at the head are

usually slip tenons, pinned, or with dovetail keys inserted. These joints in a modern door would be secured either with a hammer-headed key or handrail bolts.

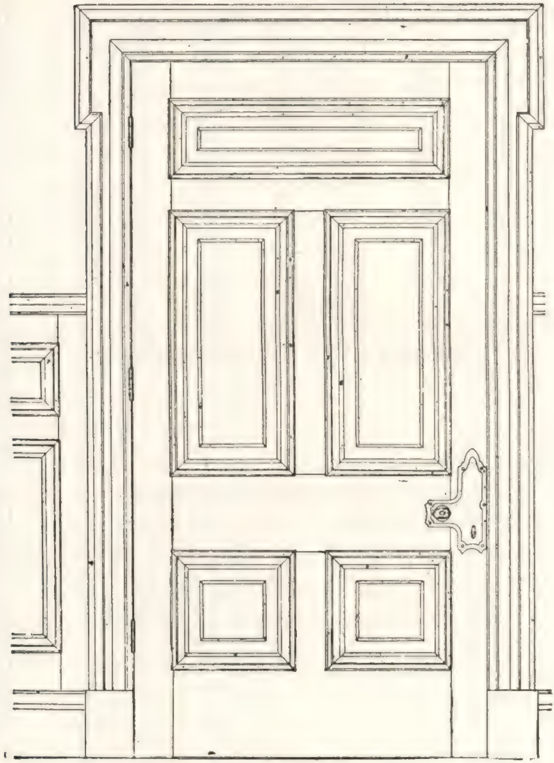


Fig. 160.

Fig. 160 shows the elevation of a superior five-panelled interior door with its finishings. Fig. 161 shows a vertical section through the opening, and Fig. 162 is

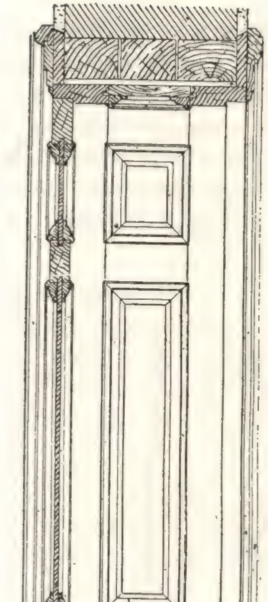


Fig. 161.

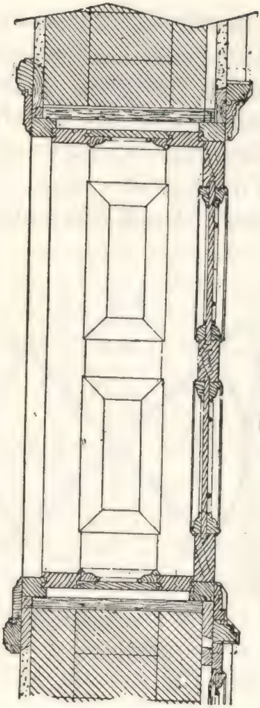


Fig. 162.

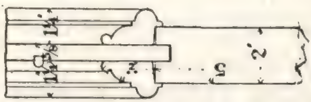
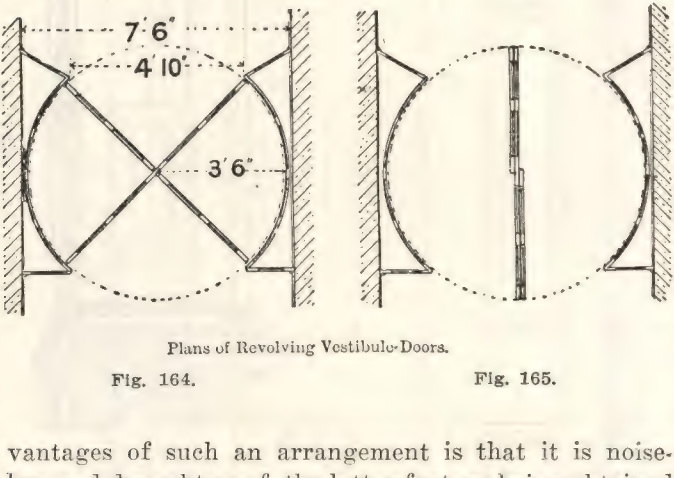


Fig. 163.

a plan showing in outline the framed soffit lining. Fig. 163 is an enlarged section of one stile and part of panel, mouldings, etc.

Revolving Doors.—An arrangement of vestibule doors, suitable for banks, hotels, etc., is shown in plan in Fig. 164. The doors are arranged at right angles to each other, and revolve around a vertical axis like a turn-stile. Curved side frames, each a little wider than a quarter of a circle, are fixed on each side of the doorway. A suitable width for the doors is 3′ 6″. The ad-



Plans of Revolving Vestibule-Doors.

Fig. 164. Fig. 165.

vantages of such an arrangement is that it is noiseless and draughtproof, the latter feature being obtained by having an india-rubber tongue fixed in the outer edge of each door. The doors are so hung that alternate doors can be folded back against the adjacent ones (Fig. 165), and thus give an uninterrupted passage when required.

Other Panelled Framing.—Framework filled in entirely with wooden panels, or with wooden panels in the lower part and glass in the upper part, is also required in the fittings for offices, for school partitions,

and for screens in churches, business premises, etc. The arrangement of the framing is similar to that of doors, and the same terms are used to describe the various parts, the only difference being the proportions of height and width; these are, of course, governed by special requirements.

Superior Doors.—In superior work, where the doors and surrounding framework are made of ornamental hardwood, it is often necessary to construct a door which shall be of one kind of wood on one side of the door and an entirely different kind on the other side. This would be necessary, for example, with a door opening from an entrance hall fitted entirely with oak into a room, the fittings of which must all be of walnut or mahogany. Such a door may be constructed in two thicknesses, each of the respective kind of wood, and each of a thickness equal to one-half of that of the finished door. The two parts are then secured together by tapering dovetailed keys, and the edges of the door are afterwards veneered to match the side of the door to which they correspond. Figs. 166 and 168 give details of this kind of door.

Grounds.—The architraves surrounding an opening are nailed to the lining, or where possible to the frame. In the best class of work, however, it is usual not to fix the door frames until the plastering is finished. Rough wooden battens or **Grounds**, of thickness equal to that of the plaster, are fixed to the walls around all door and window openings. These serve as a guide to the plasterer, and the door frames and the surrounding architraves are secured to them. When it it not desirable to have any nail holes visible in the

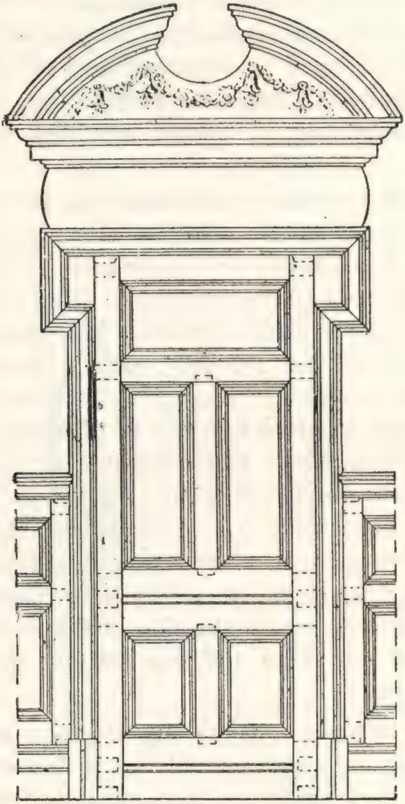
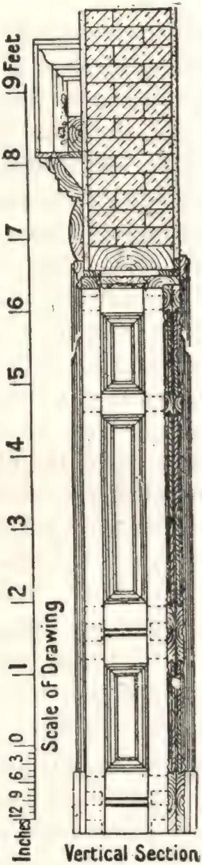

Elevation

Fig. 166.



Vertical Section

Fig. 167.

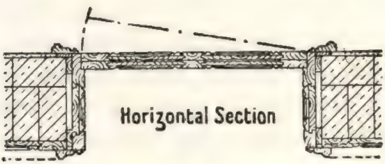


Fig. 168.

finished surfaces, the door frames and architraves are fixed by screws.

The fixing of the architraves around such a doorway affords a good example of **Fixing by Secret Screwing.** The mitres of the architraves are first glued and secured with dovetail keys or slip feathers. Stout screws are turned into the grounds about 12″ apart, being left so that the head of the screw projects about half-an-inch in front of the surface. On the back side

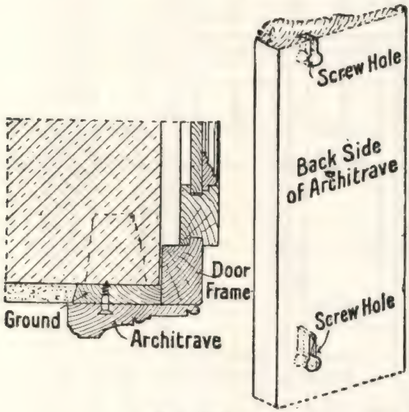
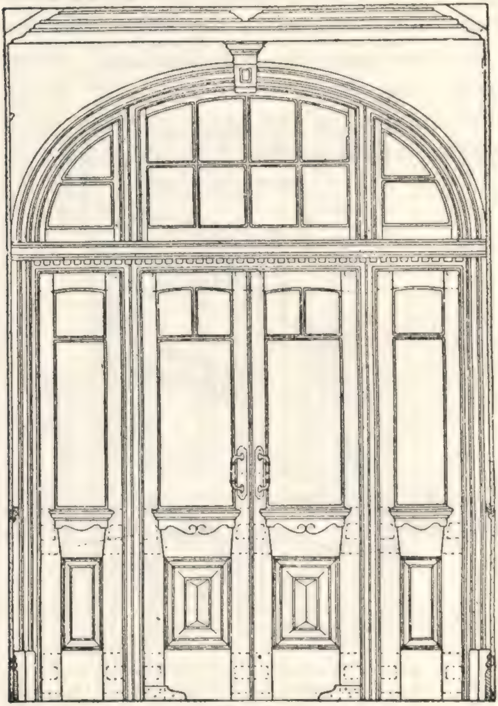


Fig. 169.

of the architrave, exactly opposite the screw heads, small holes—equal to the size of the shanks of the screws—are bored; and about three-quarters of an inch below these, larger holes—of size equal to the heads of the screws—are bored. Each small hole is connected to the large one adjacent to it by a slot, the depth of which is slightly greater than the projection of the screws. The architrave is fixed by placing

it against the wall with the larger holes fitting on the screws, and then carefully driving it down so that the heads of the screws hook into the fibres behind the



Elevation

Fig. 170.

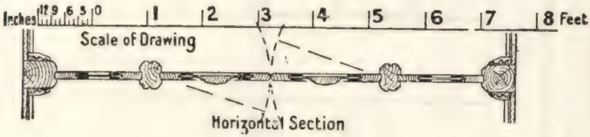
Vertical Section

Fig. 171

slots. By placing the screws so that they are slightly inclined, the tendency is to draw the architraves closer to the wall. Fig. 169 shows the explanatory detail.

The above remarks upon door frames, linings, etc., apply especially to the doors of dwelling-houses. Door

frames for warehouses, workshops, outbuildings, etc., do not as a rule require linings or architraves, a small fillet being nailed into the angle between the door frame and the wall instead. Vestibule doors are often hung to swing both ways, and the door frames have a hollow rebate or groove in the middle of the width of the frame, to receive the rounded edge of the door (Figs. 170, 171 and 172). Many of the heavier kinds of framed and ledged doors are not provided with wooden frames but are hung with bands and gudgeons, or arranged to run on pulleys as described elsewhere.



Details of a pair of Vestibule Doors with Side-lights.

Fig. 172.

Fig. 173 shows an ordinary sash door with three panels below. Fig. 174 shows a section of door and frame. Fig. 175 shows plan of door and part of cross section of frame. Fig. 176 shows the height and width rod of a door, which guides the workman in laying out his work.

External Doors are invariably hung in **Solid Frames.** Internal doors, chiefly to build up casings or **Linings,** of comparatively thin substance. In certain positions, such as vestibules and shop-fronts, where there are no wall openings to line, solid frames are also used for

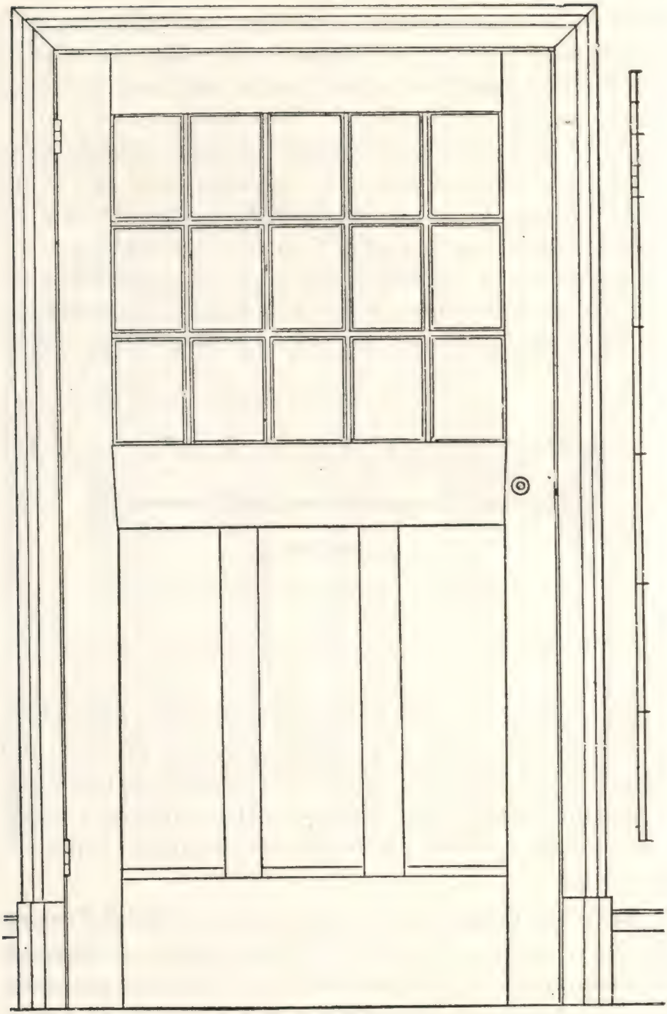


Fig. 173.

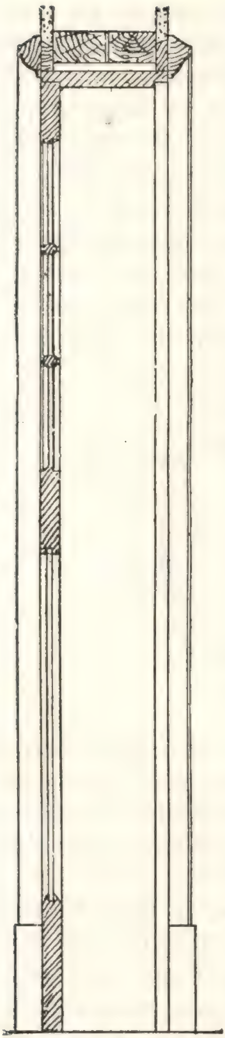


Fig. 174.

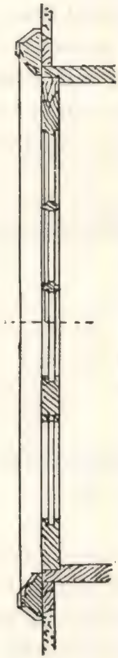
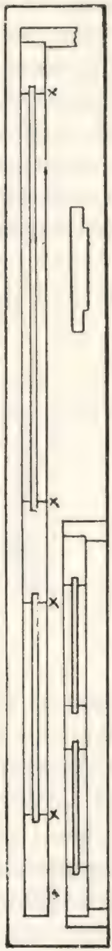


Fig. 175.



Height and Width Rod of a Door.

Fig. 176.

interior doors. The members of solid frames are usually made of square section or slightly thicker than wide; this arrangement may, however, be varied to meet the necessities of the design; the rebates, stops, mouldings, &c., are worked in the solid. The outer vertical members of these frames are called josts or jambs; interior ones, mullions. The horizontal members are sill, transom and head. The jambs are framed between the head and sill, chiefly that the ends or horns of the latter may run beyond the frame, and so provide fixings that can be built into the wall; and

A Segment-headed Frame.

Fig. 177.

also because the shoulders of the post form a better abutment for carrying any load that may be thrown on the head than the edge of a tenon would. Transoms are cut between the jambs and also between the mullions when these are used.

A Segment-headed Frame is shown in Fig. 177, and enlarged details of the joints in Figs. 178, 179, 180. The heads of these frames are cut out of the solid when the rise will permit of their being cut from pine of ordinary width. When this cannot be done, they are

made in two lengths, jointed at the crown, and fastened with a handrail bolt. The horns are taken out level at the springing line, and the back is made roughly parallel to the shoulders for convenience in fixing. When the frame is 4 in. and upwards in thickness, double tenons should be used, as shown in Fig. 179; and if the position in which the frame is to be fixed does not admit of the horns being left on, the mortises should be haunched back, as shown in Fig.

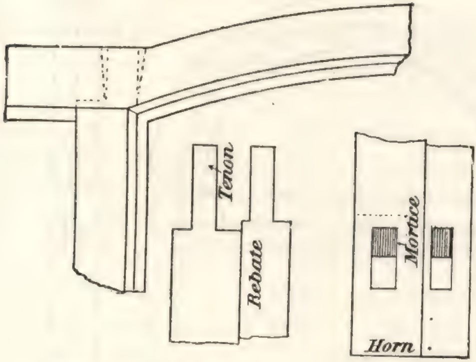
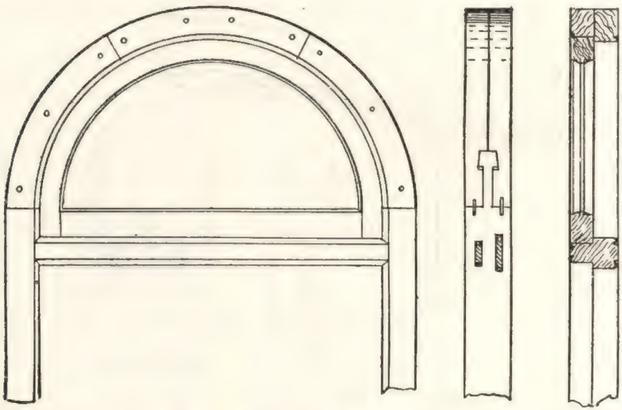


Fig. 178. Fig. 179. Fig. 180.

180, although the horns would not be cut off until the frame was fixed, as they would be required for the purpose of cramping up the frame.

A Semi-headed Frame may have its head cut in two or three lengths and bolted together, but is frequently built up as shown in Figs. 181, 182, 183. The jambs and transom are worked solid, but the head is formed in two thicknesses glued and screwed together, one

layer being in two lengths, the other in three, so as to break joint. This is both a strong and economical way of forming a head, because the grain is less cut across than it would be in a head cut out of one thickness, and the labor of rebating is also dispensed with, the inner ring being kept back ½ in. to form a rebate. The head is fastened to the jambs by hammer-head tenons and shoulder tongues, as shown in Fig. 182, and double tenons are used for the transom to



A Semi-headed Solid Frame.

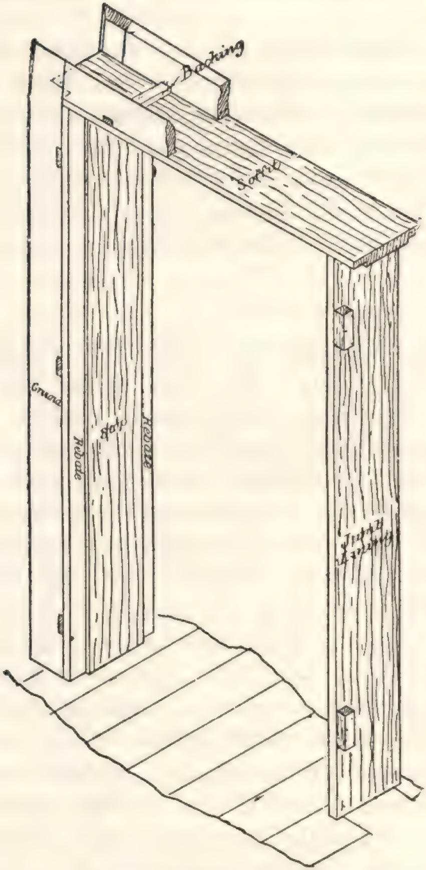
Fig. 181. Fig. 182. Fig. 183.

avoid cutting the root of the head tenons. The transom is better kept about 3 in. below the springing as shown, to ensure a strong joint. But if the exigencies of the design necessitate its being placed at the springing, then the jamb should be carried above the springing and a portion of the curve worked upon it, because

if the two joints are made together, the connection will be very weak.

There are four varieties of door casings or **Jamb Linings** as they are also termed, viz., **Plain, Framed, Double Framed,** and **Skeleton Framed,** these names defining the method of construction. Other sub-names are also used denoting the nature of the ornamentation, as in doors, with which they agree in the general arrangement of their parts. The term **Plain** is applied to any wall lining however it may be treated, if it is made of one flat board or surface.

A "Set" of Linings comprise a pair of jambs and a head or soffit lining. The flat, against the edge of which the door rests when closed, is called the **Stop,** and in common work these are merely nailed upon the surface of the main lining, being kept back from the edge sufficiently far to form a rebate for the door. In better work the rebate is worked in the solid, the lining in such case being thicker. Not less than 1½ in. stuff should be used for any lining to which a door has to be hung, as the rebate takes ½ in. out of the thickness, leaving only 1 in. for screw hold for the hinges. This, however, may be supplemented by hinge blocks glued to the back of the lining just behind where the hinges will be inserted, as shown on one side of the isometric sketch of a set of **Plain Jamb Linings** (Fig. 184). When the lining is rebated on both edges, it is said to be "double rebated." Plain linings are not suitable for walls thicker than 14 in., in consequence of the amount of shrinkage which disarranges the finishings, and even in 14 in. work they are better framed.



Isometric Sketch of a Double
Rebated Set of Plain Linings with Double
Set of Grounds.

Fig. 184.

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